Battaglia, Frank

From: Lynch, Joanne <Joanne.Lynch@aecom.com>
Sent: Monday, February 22, 2016 2:02 PM
To: Battaglia, Frank
Cc: Joseph Guarnaccia; Hellerich, Lucas; Henderson, Rory; Hansel, Kelly; Atter, Steve
Subject: Former Ciba-Geigy Property, 180 Mill St, Cranston, RI - CMS DRAFT Final Text & Figure Revisions - For Your Review and Approval
Attachments: BASF_CMS_DRAFT_Final 2016-02-22.docx; Figure_18A_Soil_Selected_Remedy.pdf; Figure_18B_Soil_Selected_Remedy.pdf

Frank – Attached is the revised text of the BASF Corrective Measures Study for 180 Mill St, Cranston, RI in red-line-strike-out format. The text reflects changes in response to EPA comments provided to BASF on 1/29/16. Below is a memorandum from Joe Guarnaccia at BASF that explains the text modifications. Please do not hesitate to contact me if you have any comments or questions. Best Regards, Joanne

From the desk of Joseph Guarnaccia (BASF):

01/29/2016
Frank,

This is a CMS revision that addresses the issues you raised with me on 1/29 when we spoke. Specifically, we altered the Executive Summary and Section 6 and some figures to add the following information:

1. River cap: Provide the following,
    a. The basis for the 13' as a flood trigger.
    b. There needs to be a finish point based on future monitoring (an out).
    c. Details on the cap monitoring are needed.

2. River lot, soil – Detail added:
    a. Reference that the remedy will follow TSCA rules and meet RIDEM criteria. 4 Phases: [1] Remove >50ppm and verification sampling; [2] Remove >10ppm and verification sampling; [3] Consolidate, put down witness barrier, and cap >1ppm. Where cleared < 1ppm, confirmatory sampling. The cap will be completed to support diverse upland habitat (an example added); [4] ELUR to be approved by the DEM.
    b. Detailed implementation design and sampling and performance monitoring plans will be developed following this outline.

3. River Lot – GW –detail added:
    a. Upland, remove VOC-impacted soil and mix in chemical oxidant to destroy mass in-situ.
    b. Along the river: install and operate a reactive barrier – inject/percolate O_3 into the upland aquifer along a transect parallel to the bulkhead to destroy VOC mass in-situ before to can migrate offsite. Describe the plan: [1] pilot test to determine design parameters, specifically: spacing of injection points, orientation of injection points (H or V), need for aquifer permeability enhancement to improve contact and continuity. Describe performance sampling: sample GW upstream, at, and downstream of the wall. Sample for VOC, geochemistry, etc. [2] Install the full scale system based on pilot-driven design. Performance monitoring will be used to operate the barrier and determine its effectiveness, and determine its need over time. Performance will be concentration-based, below MPS. ISCO will support aerobic biodegradation, which is a component of natural attenuation.
    c. Site-wide – MNA – over time, in concert with and in lieu of ISCO efforts, monitor groundwater conditions to determine whether natural attenuation is sufficient to address residual groundwater impact such that the river receptor is protected. Monitoring parameters include, ...
    d. Detailed implementation design and sampling and performance monitoring plans will be developed following this outline.

Based on our discussion, the following approval procedure is as follows:

1. Provide EPA revised text as outlined above to replace text in the current CMS. See attached RLSO which includes only changes from the last revision you received. Section 6 and the ES.

2. EPA to approve the changes, and BASF issues a FINAL CMS.
3. EPA/BASF develop the SOB.
4. We post the following docs in the library, DEM and EPA, internet: SRIWP, SRI, CMS, SOB (other?).
5. Open comment period (30d). Publish alerts in paper. Coordinate with Stycos and DEM and City (mayor) for an information session (March (?) time-frame). Short introductory presentation explaining what was done, then open room to discussion. Have stations: Building lots (real estate), River Lot (soil work, GW work). Posters providing enough detail for someone to understand why we are doing what we are doing and what to expect in terms of project duration, operation (trucks, noise, dust), methods (dig, stage, haul, cap, habitat restoration). O3 remedy. Bellefont will not be included given its review status.
6. After 30d EPA responds to comments if any.
7. EPA issues BASF a letter of remedy approval (i.e., the remedy as outlined in the SOB is approved). With this we can get going with remedy. BASF to implement building lot remedy first (simple excavation and regrading and ELUR).
8. EPA develops an AOC with BASF. To be developed during the comment period, and finalized after.

Once you go through this, either provide concurrence, or let us have a call to further hone the necessary details.

Regards Joe

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BASF Corporation

Former Ciba-Geigy Facility

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Cranston, Rhode Island

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List of Acronyms and Abbreviations

2X	Two Times
AOC	Area of Concern
BGS	Below Ground Surface
CAO	Corrective Action Objective
COCs	Constituents of Concern
CMS	Corrective Measures Study
CVOCs	Chlorinated Volatile Organic Compounds
CY	Cubic Yard
DEC	Direct Exposure Criteria
DO	Dissolved Oxygen
ERD	Enhanced Reductive Dechlorination
ELUR	Environmental Land Use Restriction
FPA	Former Production Area
FWWTA	Former Waste Water Treatment Area
HI	Hazard Index
I/C DEC	Industrial/Commercial Direct Exposure Criteria
IRM	Interim Remedial Measure
ISCO	In Situ Chemical Oxidation
ISCR	In Situ Chemical Reduction
µg/kg	micrograms per kilogram
MFR	Modified Fenton's Reagent
~~mg/kgppm~~	~~milligrams per kilogram~~
MCL	Maximum Contaminant Level
MIP	Membrane Interface Probe
MNA	Monitored Natural Attenuation
MPS	Media Protection Standards
NOAA	National Oceanic and Atmospheric Administration
OWLA	Office/Warehouse/Laboratory Area
O&M	Operations and Maintenance
P&T	Groundwater Pump and Treat
PPM	Parts Per Million
PCBs	Polychlorinated Biphenyl
PDI	Pre-design Investigation
PHERE	Public Health
PPM	Parts Per Million
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RGs	Remedial Goals
RIDEM	Rhode Island Department of Environmental Management
R DEC	Residential Direct Exposure Criteria

RFI	RCRA Facility Investigation

List of Acronyms and Abbreviations (cont'd)

SMP	Soil Management Plan
SPLP	Synthetic Precipitation Leaching Procedure
SRI	Supplemental Remedial Investigation
SVE	Soil Vapor Extraction
SVOC	Semi-volatile Organic Compound
SWMU	Solid Waste Management Unit
TCLP	Toxicity Characteristic Leaching Procedure
TPH	Total Petroleum Hydrocarbons
TSCA	Toxic Substances Control Act
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WWTA	Waste Water Treatment Area

Executive Summary

AECOM has prepared a Resource Conservation and Recovery Act (RCRA) Corrective Measures Study (CMS) on behalf of BASF for the former Ciba-Geigy facility located at 180 Mill Street in Cranston, Rhode Island (the Site). The objective of this CMS is to identify, develop and evaluate potential corrective measures to address impacted environmental media at the Site. This CMS was completed in accordance with the CMS Work Plan prepared by AECOM, and approved by United States Environmental Protection Agency (USEPA) on March 10, 2014.

The Former Ciba-Geigy facility was a chemical manufacturing facility operated by Alrose Chemical Company beginning in 1930. The facility was used for batch manufacturing of organic chemicals, such as plastic additives, optical brighteners, pharmaceuticals, and textile auxiliaries. Ciba-Geigy (referred to as Ciba herein) ceased all chemical manufacturing operations in May 1986 when the plant was closed. Following closure in 1986, the production facilities were demolished to grade, where building foundations and subsurface structures were left in place. The former office, laboratory and warehouse buildings were left in place (Buildings 26, 20, 25, and 15) and remain intact as of this writing.

Investigation and remediation activities at the Site have been conducted by Ciba (now BASF) under continuous regulatory oversight of the USEPA since 1989 as part of the RCRA Corrective Action program documented in the following regulatory orders:

- USEPA Consent Order RCRA No. I-88-1088 (1989); and
- USEPA Consent Order Modification to RCRA No. I-88-1088 (1992).

In 2009 BASF Corporation (BASF) acquired Ciba, and with it, BASF retains all regulatory responsibility for the Site.

Remedial investigations (RI) and interim remedial measures (IRM) were conducted at the facility from 1990 to 2009 by Ciba. Since 2010 BASF has reviewed all the Site-related files, and conducted its own remedial investigations to fill outstanding data gaps necessary to characterize remedial measures to advance this Site to final compliance under this RCRA corrective action. A summary of the history of RI and IRM activities is provided below as the context for the proposed additional remedial measures deemed necessary to achieve RCRA closure.

A multi-phase RCRA Facility Investigation (RFI) was completed between 1991 and 1995. A separate RFI was also completed for the Pawtuxet River in 1996. The RFIs concluded that unacceptable human health and ecological risks were present primarily from polychlorinated biphenyl (PCB) and volatile organic compound (VOC) impacts in Former Production Area soil and adjacent river sediment. Media protection standards (MPS) were then derived for PCBs in soil and VOCs (chlorobenzene, 1,2-dichlorobenzene, 2-chlorotoluene, xylenes, and toluene) in groundwater. IRMs were developed and implemented in 1995 and 1996 for soil (PCB excavation and capping and soil stabilization via the installation and operation of a soil vapor extraction system [SVE]), groundwater (installation and operation of a groundwater pumping and treatment system [P&T]), and sediment (excavation and capping). From 1996 to 2010 verification sampling of impacted media was conducted periodically to verify that the IRMs were functioning as intended. From 2010 to 2015, BASF conducted document review and RI tasks to validate IRM need and effectiveness. RI tasks included several rounds of soil, groundwater and sediment data collection and analysis. The results provided a refinement to the previous environmental impact characterization and no significant exposure concerns or additional environmental impacts were discovered, thus validating the previous work performed by Ciba and the EPA.

From the BASF assessment, corrective measures for the remediation of remaining soil and groundwater impacts were screened for feasibility in the CMS Work Plan (AECOM 2014), and they are evaluated in this CMS to present alternatives that will achieve RCRA closure.

For the purposes of this CMS presentation, based on the extensive historical record of Site use, environmental data and remedial measures, the Site is separated into four sub-areas:

1. The Former Production Area (FPA) where all of the manufacturing operations occurred, where several areas of concern were identified, and where several IRMs were implemented.
2. Pawtuxet River sediments which were impacted by FPA waste discharges during facility operation and where an IRM was implemented.
3. The Office/Warehouse/Laboratory Area (OWLA), which was not identified as an area of concern by the EPA, but where Rhode Island Department of Environmental Management (RIDEM) rules and regulations apply.
4. The Former Waste Water Treatment Plant Area (FWWTA), which is located on a separate lot on Mayflower Drive, was identified as an area of concern by the EPA at the time of the RFI, and was the subject of a comprehensive property remedial investigation. ~~At the time of the remedial~~Based on that investigation, no significant environmental impacts were identified. While Ciba sold the property in 2004, the property remains part of the RCRA Site because no EPA Statement of Basis was issued, and at a minimum, remedial measures must consider RIDEM rules and regulations.

In the CMS Work Plan (AECOM, 2014) potential remedial alternatives were screened based on feasibility criteria, and based on this analysis a set of technologies were retained for further evaluation in this CMS. Several additional tasks were conducted since approval of the CMS Work Plan, and they are:

1. Implementation of a bench-scale experiment to study the efficacy and design of an in-situ biological degradation technology to address impacted groundwater.
2. Implementation of a pre-design investigation to refine groundwater remediation areas.
3. Screening of additional groundwater remedial alternatives.

Corrective Action Objectives (CAOs) provide the basis for remediation and summarize the remedial goals for corrective measures. On a RCRA Site-wide basis, the objective is protection of human health from unacceptable exposure to environmental impacts at the Site (unacceptable is defined as cancer risk greater than 1×10^{-4} and Hazard Index > 1), and protection of the environment from exposure to impacts at the Site.

At the FPA, soil and groundwater media require remedial action to provide for long-term protection of human health and the environment. With respect to soil, the presence of PCBs is the regulatory driver for remediation. The list of retained soil remediation alternatives ~~for soil~~ is provided below:

- No action
- Engineered and/or institutional controls (land use restrictions)
- Low Occupancy Re-Use Scenario (Excavation/Capping with land use restrictions)

- High Occupancy Re-Use Scenario (Excavation/Capping with land use restrictions)
- Strictest Remedial Standard (Excavation)

For groundwater, VOCs are the regulatory drivers for remediation due to their concentrations. The list of retained groundwater remediation alternatives is provided below:

- No action
- Engineered and/or institutional controls
- Monitored natural attenuation (MNA)
- In situ chemical oxidation (ISCO)
- In situ aerobic biodegradation
- Groundwater P&T – repair and operate existing system

The CAO for Pawtuxet River sediment is to ensure the existing cap integrity is protective of the environment. To meet the CAO for Pawtuxet River sediment, given the historic remedial measures completed for sediment at the Site (i.e., excavation and capping), a long-term, periodic, monitoring and reporting program is proposed to ensure the existing sand cap remains intact.

For the OWLA, while it did not constitute an AOC during the RFI, soil and groundwater sampling conducted by BASF in 2012 through 2014 indicate sporadic soil impacts of several polycyclic aromatic hydrocarbons (PAH) typical of urban environments (e.g., residues from vehicle exhaust and runoff from paved surfaces) in excess of the RIDEM Industrial/Commercial Direct Exposure Criteria (I/C DEC). These impacts will need to be addressed as per RIDEM Regulations, and to this end BASF will remove or cover the affected soil, impose an Environmental Land Use Restriction (ELUR) for this area, and include a soil management plan to be applied as part of any redevelopment work.

For the FWWTA, the alternatives for RCRA closure include No Further Action and imposing a RIDEM Environmental Land Use Restriction (ELUR) on the property.

The retained remediation alternatives were screened against a series of performance standards as specified in USEPA CMS guidance. The performance standards used in the detailed analysis of remedial alternatives are as follows:

- Primary performance standards, including:
  - Overall protection of human health and the environment
  - Attainment of media cleanup standards
  - Control of the sources of releases
- Balancing factors (used to further evaluate alternatives meeting all three primary performance standards)
  - Long-term reliability and effectiveness
  - Reduction in the toxicity, mobility, or volume of wastes
  - Short-term effectiveness
  - Implementability and environmental footprint

- Cost
- State and community acceptance

Based on detailed analysis of the retained alternatives the following remedy is proposed to address COCs in soil at the Site:

FPA:

Remediate PCB-impacted soil to meet a High Occupancy Re-Use scenario. The goal associated with this remedy is to allow the entire FPA to be repurposed as publically-available open space (parkland). This will be achieved by removing soil containing PCBs greater than 10 ppm and installing a clean soil cover (cap) over ~~remaining~~ areas where soils contain PCBs greater than 1 ppm. The soil cover will be constructed and maintained to support an ecologically varied upland habitat.

The remedy will follow a four step plan consistent with both EPA (TSCA) and RIDEM requirements: [1] Excavation, verification sampling and offsite disposal of all TSCA-classified soil (i.e., soil impacted with greater than 50 ppm of PCBs); [2] Excavation, verification sampling and offsite disposal of all soil impacted with greater than 10 ppm of PCBs (i.e., the EPA requirement to allow for a high-occupancy reuse scenario); [3] Cover (cap) remaining soils with concentrations greater than1 ppm with two feet of clean soil and confirmatory sampling to meet RIDEM direct exposure requirements . The cap will be completed to support a diverse upland habitat; [4] Impose an Environmental Land Use Restriction (ELUR) on the parcel, to be approved by the RIDEM, requiring, at a minimum, open space (parkland) reuse only and long-term cap maintenance and monitoring. Details of the four step plan will be provided during the design-phase of the corrective action. ~~Caps used as remedial measures under TSCA 40 CFR 761.61(a)(7) are required to meet permeability, sieve, liquid limit and plasticity requirements. The cover requirements needed to render soil inaccessible meet the minimum thickness requirements for compacted soil caps required by §761.61(a)(7); however, since the soil cap is used for compliance with the DEC, a low permeability layer is not required by RIDEM.~~

Remediate VOC-impacted Groundwater to restore the upland aquifer and protect the Pawtuxet River. Groundwater will be addressed through a three step plan. First, residual VOC source material located in the upland near SWMU11 will be in part excavated from the vadose zone and disposed of offsite and in part destroyed in-situ with a chemical oxidant (activated sodium persulfate) by physically mixing the oxidant into the vadose and saturated zones before re-grading the area to support the soil cover.

Second, for the groundwater plume that has migrated to the vicinity of the river bulkhead, an in-situ reactive barrier will be installed parallel to the river bulkhead and normal to the groundwater flow direction to destroy VOC mass in-situ before it migrates off-site and discharges to the Pawtuxet River. The proposed oxidant is ozone, and it will be applied to the aquifer in a continuous fashion using a line of wells that overlap in their volume of influence (a sparge application). The ozone will destroy all contamination in which it comes in contact, and it will also contribute oxygen to the groundwater to support aerobic biological degradation. Remedy performance will be monitored using dedicated wells installed upgradient, within and downgradient of the barrier along flow lines. The remedy will be run on the order of years until such time as downgradient monitoring show that the media protection standards are consistently met. ~~abiotic and biotic chemical destruction processes will be installed to destroy contaminant mass in place thereby controlling mass discharge from the site to the river.~~ The remedy design including the treatment volume, ~~of aquifer~~ number and orientation of injection wells, and monitoring requirements ~~to which the remedy will be applied~~ will be determined from a pilot testing program.

Third, for dissolved upland VOC mass in general, monitored natural attenuation (MNA) will be used to show ~~mass attenuation~~aquifer restoration over time. A monitoring program will be implemented to analyze trends of COCs and pertinent MNA parameters upgradient and downgradient of the reactive barrier. The performance monitoring parameters and frequency will be outlined in a Remedial Action Work Plan, but they typically include sampling for the COCs, geochemistry (e.g. dissolved oxygen, specific conductivity, pH, turbidity), total organic carbon, terminal electron acceptors (e.g. nitrate, sulfate, iron), and occasional bacterial census to evaluate whether bacterial populations at the Site continue to be present in sufficient numbers to effectively treat COCs. Performance monitoring evaluations will be conducted in concert with the ISCO barrier performance evaluations to determine whether natural attenuation is sufficient to address groundwater impacts in concert with or independently of the ISCO barrier approach. It is anticipated that over time MNA will become the sole groundwater remedy based on the record of spatial and temporal trends in COC concentration.

These remedial measures in concert are appropriate given site-specific conditions including extensive in place building foundations which limits access to aquifer materials and low conductivity heterogeneous aquifer material coupled with the age of the impacts (greater than 40 years) which limits the mobility of the dissolved-phase mass. Finally, this remedy is consistent with that proposed for the upland soils and the imposition of an ELUR that will limit future land use to open-space and require long-term operation and maintenance.

Pawtuxet River Sediment

Given the historic remedial measures completed for sediment at the Site, a long-term periodic monitoring program will be implemented to ensure the existing sand cap remains intact and protective. Monitoring frequency is initially proposed to occur at the first five year review (2021) and after major flood events between now and that time (defined by NOAA as a Pawtuxet River stage that exceeds 13 ft MSL at the USGS gage station 01116500). Under the monitoring plan ~~the,~~ the sand cap will be sampled for PCB content to ensure that any remaining PCBs sequestered below the cap are not permeating the cap. Cores of the cap will be collected along the center line at upstream, midstream and downstream locations (3 cores) and samples will be collected for PCB analysis from the 0" to 3" and 3" to 6" horizons (2 samples per core). If PCBs exceed 1 ppm in any sample, additional investigation will be conducted to determine the source of the detections and appropriate remedial measures necessary to ensure protectiveness, if any. A detailed monitoring and sampling plan will be developed following this outline. At the time of the 5 year review, based on the data in hand, a decision will be made as to the permanence of the remedy and future monitoring requirements.~~To meet Corrective Action Objectives for sediment, given the effectiveness of the historic remedial measures completed for sediment at the Site (i.e., excavation and capping), a long-term periodic monitoring program is proposed to ensure the existing sand cap remains intact. Monitoring is proposed to occur every five years and after major flood events (as defined by NOAA, Pawtuxet River stage at Cranston (CRAR1) exceeds 13 feet [ft] mean sea level (MSL) at the nearest USGS gage station 01116500 (located approximately 1.5 miles upstream of the Site). The sand cap will be sampled for PCBs under a dedicated monitoring plan. If PCBs within the sand cap exceed 10 parts per million (ppm), additional investigation will be performed, and additional remedial measures may be warranted. The sampling plan will be developed and provided under separate cover~~

OWLA

To address RIDEM Regulations, BASF will remove or cover the soil with exceedances of the I/C DEC and impose an ELUR for this area to be approved by the RIDEM. The ELUR will include the following restrictions: non-residential use only, must employ a soil management plan for any invasive work conducted on the property, and must, on an annual basis, report to the RIDEM that the terms of the ELUR are being met.

~~To address RIDEM Regulations, BASF will remove or cover the soil with exceedances of the I/C DEC, and impose an Environmental Land Use Restriction (ELUR) for this area to be approved by the RIDEM. The ELUR will include the following restrictions: non-residential use only, must employ, and include a soil management plan for any invasive work conducted on the property, and required annual reporting to the RIDEM verifying that the terms of the ELUR are being met. to be applied as part of any redevelopment work.~~

~~-~~FWWTA

The property was sold in 2004. To date, the USEPA has not issued a Statement of Basis outlining the regulatory decision on the property, and as such, it remains part of this CMS. Soil characterization data include sporadic detections of a commonly used insecticide, chlordane, naturally occurring arsenic, and benzo(a)pyrene and dibenz(a,h)anthracene, which are commonly identified in urban settings. These data are located within the 200-foot riverbank wetlands zone, which precludes development and soil management without RIDEM approval. Further, a human health risk assessment completed in 1995 (Ciba, 1995) determined that there was no significant risk for a conservative future use scenario of an on-site resident (despite the commercial zoning designation). Therefore, the remedy for this area is No Further Action.

1.0 Introduction

This Resource Conservation and Recovery Act (RCRA) Corrective Measures Study (CMS) has been prepared on behalf of BASF Corporation (BASF) for the former Ciba-Geigy facility located at 180 Mill Street in Cranston, Rhode Island (the Site) and a former Waste Water Treatment Area (FWWTA) located at Mayflower Drive in Cranston, Rhode Island. The objective of the CMS is to identify, develop and evaluate corrective measures (remedial actions) to address impacted environmental media at the Site. In 2009 BASF Corporation (BASF) acquired Ciba Specialty Chemicals [Ciba] (the successor to Ciba-Geigy), and, as Site owner, BASF is currently involved in an ongoing, comprehensive RCRA Corrective Action Program at the Site. This program is being governed by RCRA Consent Order No. I-88-1088 (1989) and Consent Order Modification to RCRA No. I-88-1088 (1992) between the United States Environmental Protection Agency (USEPA) Region I and BASF. This CMS is being prepared to satisfy the requirements of the consent orders and has been developed in accordance with the CMS Work Plan (AECOM, 2014), approved by USEPA on March 10, 2014.

1.1 Corrective Measures Approach and Site-Specific Purpose

For the purposes of this CMS presentation, based on the extensive historical record of Site use, environmental data and remedial measures, the Site is separated into four sub-areas:

1. The Former Production Area (FPA) where all of the manufacturing operations occurred, where several areas of concern were identified, and where several IRMs were implemented.
2. Pawtuxet River sediments which were impacted by FPA waste discharges during facility operation and where an IRM was implemented.
3. The Office/Warehouse/Laboratory Area (OWLA), which was not identified as an area of concern by the EPA, but where Rhode Island Department of Environmental Management (RIDEM) rules and regulations apply.
4. The Former Waste Water Treatment Plant Area (FWWTA), which is located on a separate lot on Mayflower Drive, was identified as an area of concern by the EPA, and was the subject of a comprehensive property remedial investigation. At the time of the remedial investigation, no significant environmental impacts were identified. While Ciba sold the property on 2004, the property remains part of the RCRA Site because no EPA Statement of Basis was issued, and at a minimum, remedial measures must consider RIDEM rules and regulations.

The purpose of the CMS portion of the RCRA corrective action process is to identify, evaluate and propose remedial technologies and alternatives for addressing potentially hazardous constituents associated with these areas. Remedial technologies not presented in this CMS were excluded during the development of the CMS Work Plan (AECOM 2014) based on site conditions and contaminant and technology characteristics.

The CMS is designed to address the following objectives:

- Identify media-specific cleanup standards;

- Identify potential treatment technologies, containment/disposal, and institutional/engineering control options for soil, sediment, and groundwater that contain COC impacts above established cleanup standards;
- Screen feasible remedial technologies;
- Assemble technologies into alternatives;
- Analyze the identified alternatives using specific evaluation criteria and media cleanup standards;
- Compare alternatives against each other using the evaluation criteria; and
- Recommend remedial alternatives.

1.2 Report Organization

This CMS is organized into nine sections.

- **Section 1.0** presents the introduction, a summary of the CMS objectives and the purpose of the CMS.
- **Section 2.0** presents a brief history and current status of the Site.
- **Section 3.0** summarizes the corrective measure objectives as they pertain to the applicable federal and state remediation standards.
- **Section 4.0** presents a summary of screening process for the remedial alternatives selected in the CMS Work Plan. This section is further organized to present remedial alternatives by media
- **Section 5.0** presents a detailed analysis of selected corrective measure alternatives.
- **Section 6.0** presents an evaluation of the selected corrective measure alternatives.
- **Section 7.0** presents the references used herein.

2.0 Site History and Current Status

2.1 Site History

The Site was a chemical manufacturing facility operated by Alrose Chemical Company beginning in 1930. It consists of the FPA, the Pawtuxet River sediments, the OWLA and the FWWTA (**Figure 1**).

The Geigy Chemical Company of New York purchased the facility in 1954 and later merged with the Ciba Corporation in 1970. The facility was used for batch manufacturing of organic chemicals, such as plastic additives, optical brighteners, pharmaceuticals, and textile auxiliaries (Ciba, 1995). Ciba-Geigy (Ciba) ceased all chemical manufacturing operations in May 1986 when the plant was closed. Following closure in 1986, the production facility was demolished to grade, where building foundations and subsurface structures were left in place. The former laboratory and warehouse buildings were left in place (Buildings 26, 20, 25, and 15) in the northern portion of the Site. **Figure 2** shows the current layout of the Production Area and where historic site structures/features were located. The FWWTA that is located on Mayflower Drive, and it was decommissioned and sold in 2004. A detailed history of the Site, Site use, and an overview of applicable regulatory drivers and requirements were provided in the Phase II RCRA Facility Investigation (RFI) (Ciba-Geigy Corporation, 1995).

In 2009, BASF Corporation (BASF) acquired Ciba, and with it, BASF retains all regulatory responsibility for the Site. BASF conducted additional characterization of groundwater and soil and derived an updated conceptual site model for the Site. This work is documented in the Supplemental Remedial Investigation (SRI) Report (AECOM, 2012) and SRI Revision (AECOM, 2014).

2.2 Regulatory History and Status

As with many other industrial facilities with long operational histories, contaminants of concern (COCs) have been identified at the Site. Some of these COCs eventually migrated to groundwater at the FPA and were found in the aquifer and sediment beneath the Pawtuxet River adjacent to the FPA.

Investigation and remediation activities at the Site have been conducted by Ciba (now BASF) under continuous regulatory oversight of the USEPA since 1989 as part of the RCRA Corrective Action program documented in the following regulatory orders:

- USEPA Consent Order RCRA No. I-88-1088 (1989); and
- USEPA Consent Order Modification to RCRA No. I-88-1088 (1992).

Remedial investigations (RI) and interim remedial measures (IRM) were conducted at the facility from 1990 to 2009 by Ciba. Since 2009, BASF has reviewed all the Site-related files, and conducted its own remedial investigations to fill outstanding data gaps necessary to characterize remedial measures to advance this Site toward final compliance under this RCRA corrective action. A summary of the history of RI and IRM activities is included below to provide context for proposed additional remedial measures deemed necessary to achieve RCRA closure.

- FPA and OWLA investigations are described in the Supplemental Remedial Investigation (SRI) Report (AECOM, 2012) and SRI Revision (AECOM, 2014).
- The Phase II RFI (Ciba, July 31, 1995) included Site source characterization, soil and groundwater characterization, and fate and transport and risk evaluation.
- The Pawtuxet River RFI (Ciba, March 31, 1996) included physical characterization, source characterization, release characterization and river modeling investigations as well as a Baseline Ecological Risk Assessment.
- Remediation activities for the FPA soil, groundwater and sediment are described in the On-Site Corrective Measures Study (Woodward-Clyde, 1995), On-Site Soil Interim Remedial Measures (Woodward-Clyde, 1996), Sediment IRM for the Pawtuxet River (Woodward-Clyde, 1996), and the Sediment IRM Report (AECOM, 2012).

The Phase II RFI was completed and documented in a report to USEPA (Ciba, 1995). A Public Health and Environmental Risk Evaluation (PHERE) was completed as part of the RFI, per the Order (USEPA, 1989). The PHERE evaluated potential human health and ecological risks associated with each operational area. For the FPA unacceptable human health and ecological risks were identified primarily from PCB and VOC impacts in soil, groundwater, and sediment. To mitigate these impacts and provide a basis for necessary Interim Remedial Measures (IRM), site-specific Media Protection Standards (MPS) were developed. The IRMs were developed and implemented in 1995 and 1996 for soil (PCB excavation and capping and soil stabilization via the installation and operation of a soil vapor extraction system [SVE]), groundwater (installation and operation of a groundwater pumping and treatment system [P&T]) and sediment (excavation and capping). The SVE system was operated from 1997 to 2005, when, based on the conditions that it had reached its asymptotic end point and post-operation verification sampling showed that the MPS was achieved, it was determined that the system had addressed the soil impacts. The P&T operated from 1996 to 2006 when performance monitoring showed that the MPS had been achieved. Continued monitoring showed a rebound in concentrations in the southeast corner of the property in 2008, and this triggered a remedial investigation to delineate the recalcitrant zone, and remediation of this zone is in part the subject of this CMS.

Since the Phase II RFI (RFI On-Site Areas, Ciba Corporation, 1995), a significant amount of field work has been completed in the FPA and OWLA, including IRM implementation and verification monitoring conducted by Ciba through 2009 and remedial investigation activities conducted by BASF from 2010 through 2015. Based on the findings of the SRI (AECOM, 2012), SRI Revision (AECOM, 2014), and additional pre-design investigation (PDI) data collected to refine groundwater remediation areas (completed during September 2014), well-delineated areas of soil and site-related groundwater at the FPA were found to require remedial action over and above the IRM measures previously applied. Specifically, this characterization shows that subsurface soils contain PCBs above current remediation standards, and there is a localized groundwater zone that is impacted with site COCs above the MPS.

While the OWLA was not identified as an AOC during the RFI, soil and groundwater sampling conducted by BASF in 2012 through 2014 indicate sporadic soil impacts of several polycyclic aromatic hydrocarbons (PAH) typical of urban environments (e.g., residues from vehicle exhaust and runoff from paved surfaces) in excess of the RIDEM Industrial/Commercial Direct Exposure Criteria (I/C DEC). These RIDEM criteria are applicable or relevant and appropriate requirements (ARARs) that will need to be addressed.

With regard to the Pawtuxet River sediments, a Phase II RFI was completed by Ciba-Geigy in 1996 (RFI Pawtuxet River, Ciba Corporation, 1996). The RFI concluded that excavation, disposal and capping of impacted sediment from the former cofferdam area in the river adjacent to the FPA would significantly reduce the concentrations of Site COCs in river sediment. This assessment provided the basis for a subsequent IRM to provide "significant, long-term reductions in contaminant concentrations" within the Upper Facility Reach of the Pawtuxet River, where over 2,225 tons of contaminated sediment was excavated and replaced with clean sand (Sediment IRM Pawtuxet River, 1996). Periodic sediment sampling conducted by Ciba verified the intent of the IRM. Moreover, after a 100 year flood event in 2010 and following a request by the EPA, BASF confirmed that the sand cap emplaced over the former cofferdam area and witness barrier were still present (AECOM, 2012). Additional sediment sampling immediately upstream and downstream of the capped area was also completed at that time. While the cap was shown to be intact and functioning as intended, sediment analytical results outside the capped area indicated that three discrete areas of sediment continued to contain residual PCBs. In 2012, BASF voluntarily addressed these areas by excavation and capping with clean sand. A total of 23 CY of impacted sediments were removed from the Pawtuxet River and disposed off-site at appropriate facilities (AECOM, 2012).

Figure 3 illustrates the IRMs completed in the FPA related to soil, groundwater, and sediment in the Pawtuxet River adjacent to the FPA.

With regard to the FWWTA, the RFI risk evaluation concluded that risk associated with site-related soil and groundwater impacts met the conditions for unrestricted future use. Groundwater did not exceed any applicable risk-based standard. For soil, this conclusion was based on the risk calculation result that the hazard index (HI) for non-cancer compounds was less than 1 (actual HI = 0.4), and the total lifetime cancer risk was 3×10^{-5}, which is within the USEPA target risk range of 1×10^{-4} and 1×10^{-6}. Given the conclusions of the risk evaluation, no IRMs were required for the FWWTA.

It is important to note that the more recent characterization conducted by BASF is consistent with that derived during the original RFI in terms of COCs, their location and magnitude, and protective exposure assumptions. In addition, it provides a data-based refinement of the nature and extent of site-related impacts upon which to design and implement additional corrective actions to achieve RCRA closure.

For the sub-sections that follow the reader is referred to the following figures that illustrate the major site attributes including: hydrogeology (**Figure 4A** and **4B** are groundwater flow maps and **Figure 5** is a hydrogeologic cross section), investigation sampling locations (**Figure 6**) provides multi-parameter groundwater and soil sampling locations and **Figure 7** provides PCB sampling locations), groundwater impacts above relevant regulatory standards (**Figure 8**), and PCB distribution in shallow soils (**Figure 9**).

2.3 Site Geology and Hydrogeology

Detailed summaries of the geology and hydrogeology of the Production Area are included in the 1995 RFI submitted to USEPA by Ciba Corporation (1995). The stratigraphy of the production area is characterized based on data from the Stabilization Investigation Report and Design Concepts Proposal (Ciba, 1993), the RFI (Ciba, 1995) and the recent soil borings completed on-site between 2007 and the present. The comprehensive representation of the hydrogeology is provided in **Figures 4A and 4B**.

The production area is underlain by urban fill (2 to 8 feet thick), including sand, silt and gravel, as well as concrete and metal debris. Below the fill is a silty sand unit (10 to 15 feet thick) of alluvial origin. In the southwest quadrant of the area a fairly homogeneous unit of gray silt of alluvial origin is present

(2 to 10 ft in thickness beginning approximately 10 to 15 ft below the ground surface and of low hydraulic conductivity). Below these units (where present) exists a heterogeneous mixture of gray sand, silt, clay, and gravel of glacial outwash origin). A unit of relatively homogeneous fine sand and silty sand is the next unit encountered in depth. Finally, a 5 to 10 foot thick glacial till unit directly overlies bedrock in the Production Area. The top of competent bedrock is present from 50 to 59 ft bgs. A description of bedrock as a quartz-biotite sandstone in the Production Area was included in the Phase IA Report (Ciba, 1991) and Phase II RFI (Ciba, 1995). A cross sectional representation of Site stratigraphy is included as **Figure 5.**

With regard to hydrogeology, shallow and deeper groundwater flow direction is generally to the southeast toward the Pawtuxet River. The water table is approximately 7 to 10 feet below the ground (ft bgs) surface across the Production Area. The vertical gradient is generally downward across the Site indicating that groundwater recharge conditions prevail. The natural discharge point for site-related groundwater is the Pawtuxet River, which is a gaining water body adjacent to the Site, as evidenced by the fact that the river stage is lower than the groundwater elevation. The groundwater flow is affected by a bulkhead wall (sheet piling) that extends to a depth of 25 ft bgs, where groundwater is deflected downward under the wall as it migrates toward the river.

2.4 Remedial Action History Summary

Multiple IRMs associated with the FPA have been implemented to address Site COCs. These include several phases of soil IRMs to address PCBs, a SVE system to address VOCs in soil, a sediment excavation and capping IRM to address PCBs and VOCs, and groundwater pump-and-treat and soil vapor extraction to reduce VOC mass in groundwater and soil. **Figure 3** provides a location map for these IRMs.

2.4.1 FPA Soil IRM

The soil data collected during the Supplemental RI (2011 to 2014) and the confirmatory soil data collected during the Revised On-Site IRM (Woodward-Clyde, 1995) were combined and presented in tabular and graphical format in the SRI Report (AECOM, 2014). See **Figures 8 and 9** which are based on the data presented in Tables 4-3 and 4-4 of the SRI (AECOM 2014). The Revised On-Site IRM describes four phases of excavation and capping with clean soil in the FPA to remediate PCB concentrations in soil that exceeded the Site MPS for PCBs with a safety factor applied (i.e., soil containing total PCBs greater than 45 ppm) [excavation extent provided in **Figures 3 and 9**]. Inherent in the IRM was the fact that impacted soil remaining below the soil cap would eventually be capped with a more robust material to eliminate potential receptor contact.

2.4.2 Pawtuxet River Sediment IRM

The Phase II RFI (Ciba-Geigy,1996) concluded that excavation, disposal and capping of impacted sediment from the former cofferdam area in the river adjacent to the FPA would significantly reduce the concentrations of Site COCs in river sediment (see location in **Figure 3**). This assessment provided the basis for implementing an IRM to provide "significant, long-term reductions in contaminant concentrations" within the Upper Facility Reach of the Pawtuxet River, where over 2,225 tons of contaminated sediment were excavated and replaced with a clean sand cap (Sediment IRM Pawtuxet River, 1996). After a flood event in 2010, in 2010/2011 BASF sampled the capped area and found it to be functioning as intended. Additional sediment samples collected at the time upstream and downstream of the capped area adjacent to the Site detected three local areas of previously unidentified elevated site-related impact. These areas were subsequently excavated, where a total of

23 cubic yards (CY) of sediment were removed and disposed off-site at appropriate facilities (AECOM, 2012).

2.4.3 Groundwater Pump and Treat/Soil Vapor Extraction System

In 1995 and 1996, the groundwater IRM was initiated in the FPA with installation and operation of a soil vapor extraction system [SVE]) and installation and operation of a groundwater pumping and treatment system [P&T] (locations shown in **Figure 3**). The SVE system was operated from 1997 to 2005, when, based on the conditions that it had reached its asymptotic end point and post-operation verification sampling showed that the MPS was achieved, it was determined that the system had addressed the soil impacts.

The P&T system operated from 1996 to 2006 when performance monitoring showed that the MPS for groundwater had been achieved. Continued monitoring showed a rebound in concentrations in the southeast corner of the property in 2008. The P&T system was re-activated and operated until the flood of April 2010 damaged several components of the system. From 2011 to 2014, BASF completed several remedial investigations at USEPA's direction to refine the conceptual site model and address any on-going Site-related groundwater impacts (documented in AECOM 2014 and see current groundwater impact **Figure 8**).

2.5 Characterization of the FPA, OWLA, and Pawtuxet River Sediments

The site-specific geology and hydro stratigraphy was derived from both historical records and past and recent boring logs (documented in AECOM, 2014 and see **Figure 5**). In general, the FPA is underlain by predominately fine grain, low permeability, sands and silts with locally coarser deposits from glaciofluvial origin (~ 50 ft thick). In the southwest quadrant of the FPA there is an extensive heterogeneous aquitard that separates a shallow and a deep aquifer. In general the permeability of the deposits decrease as one moves east to west across the site as evidenced by the production rates of wells PW-110 (40 gpm) and PW-130 (20 gpm) and PW-120 (2 gpm). The shallow geology is affected by subsurface structures (e.g., foundations and pilings) left in place during plant demolition.

In 2011 BASF conducted a thorough review of the available site reports and data in order to fully understand the nature and extent of contamination at the property and identify data gaps to support the nature and extent assessment (also called conceptual site model [CSM] development). The CSM in turn is used to derive a necessary and sufficient remedial strategy for the property. The gap analysis and CSM are presented in AECOM (2012) and further refined here with additional data collected in September 2014.

Based on historical operations and environmental data, AECOM (2012) identified areas across the property that required additional investigation. During the 1990/1991 RI (Ciba, 1991), several Solid Waste Management Units (SWMU) and Areas of Concern (AOC) were identified in the FPA, and these areas were assessed retaining the original nomenclature. In addition to the previously identified areas referenced above, AECOM (2012) identified several additional areas based on the historical record. All these areas were reviewed for completeness of characterization, data gaps were identified, and a sampling plan was derived and implemented to fill data gaps regarding ongoing environmental impact (AECOM, 2012). A description of each area is presented below including current residual impact and characterization completeness. These historical operational areas are presented on **Figure 2** and described in **Table 1.** The soil and groundwater sampling locations collected from 2011 to 2014 are shown on **Figures 6 and 7**.

<u>Associated with the FPASWMU 2, 3, 7</u>: SWMUs 2, 3, and 7 contain a former tank farm area where rail cars were off-loaded and loaded. Secondary containment was present and no spills were noted in the record. The area was initially assessed by sampling during the 1995 RFI (Ciba, 1995). Additional soil data were collected in 2012. No VOC detects were noted; SVOC detections were low and near the detection limit. Neither metals nor pesticide concentrations exceeded the RIDEM DEC industrial/commercial levels. Total PCBs were identified, but this impact is consistent with site-wide PCB impacts observed throughout the Production Area. These former SWMUs do not represent an ongoing data gap, and no further action is warranted.

<u>SWMU 4</u>: SWMU 4 was an area that contained a trash compactor where solid wastes were disposed. VOCs, SVOCs, metals, and pesticides did not exceed RIDEM DEC industrial/commercial standards. This was confirmed with soil sampled in 2012. A detection of total PCBs was noted to be >10 <u>ppm</u> from 4-6 ft bgs, but this is consistent with site-wide PCB impacts observed throughout the Production Area. This former SWMU does not represent an ongoing data gap, and no further action is warranted

<u>SWMU 8</u>: A historic spill was noted at nearby SWMU 4 and a former Site plan shows a solvent recovery facility in this area, which had not been previously identified as a specific AOC or SWMU. Sampling was performed in 2012 to evaluate this area. No impacts to surface soil by VOCs, SVOC, metals, or pesticides were noted to exceed RIDEM DEC industrial/commercial standards. A detection of total PCBs greater than 10 <u>ppm</u> from 0-2 ft bgs was documented, but this is consistent with site-wide PCB impacts observed throughout the Production Area. Adjacent groundwater monitoring locations, GW-10 and MW-13S, did not contain any detectable VOC concentrations. This former SWMU does not represent an ongoing data gap, and no further action is warranted.

<u>SWMU 11</u>: A documented toluene spill from a pipeline to a subsurface sump at Building #11 occurred in the early 1980s. An IRM SVE system was operated from 1997 to 2005 (see **Figure 3** for location) to address this release, and post-closure monitoring indicated that COCs were remediated (Ciba 2005). Soil/aquifer probing was conducted from 2012 to 2014 to delineate PCB impact in shallow soil and VOC impact in both shallow and deep soil to 40 ft bgs. Detections of total PCBs were generally observed in shallow soil consistent with site-wide PCB impacts observed within the Production Area in general and impacts observed at Buildings 10 and 18 in particular (**Figure 9**). These residual impacts will be addressed as part of the proposed soil remedial measures. The VOC data showed toluene and 2-chlorotoluene at elevated concentrations in shallow soil, at 2-6 feet bgs, in the southwest corner of this area. This area is within the SVE treatment area (**Figure 3**). PDI soil and groundwater data were collected during September 2014 from areas downgradient of the shallow soil VOC impacts. Elevated concentrations of COCs, primarily toluene and 2-chlorotoluene, were identified in shallow and deep groundwater and soil collected below the water table. Groundwater impacts are illustrated in **Figures 10A-J and Figures 11A-E**. These residual impacts will be addressed as part of the proposed soil and groundwater remedial measures.

<u>Non-Aqueous Phase Liquid (NAPL) Area Near MW-34D</u>: During installation of MW-34D in 1993, a separate phase liquid was observed, and it was assumed to be Dowtherm (a PCB-free cooling oil used in the former manufacturing process), but no confirmation sampling was completed on this material at the time. In 2012 characterization data were collected for groundwater and no indication of NAPL or dissolved residual was observed. The only indication of impact was observed at well MW-34S, where total xylenes were detected over its MPS (0.145 mg/L versus 0.078 mg/L). Shallow soil samples in the vicinity of MW-34 showed no impacts of VOCs. This well is located between the impacts observed at and downgradient of SWMU 11 to the north and the recalcitrant VOC impact zone associated with the Jet Sump Area (see next) to the south. Aquifer heterogeneity may account for this discrepancy in continuity, and it will be investigated as part of the remedial measures that address groundwater.

Jet Sump Area: In Building 16 a boiler plant jet sump, where steam, charged with process-related solvent, was condensed before being recycled, failed in the mid-1970s. Excessive erosion associated with the failure went undetected and much of the condensate percolated into the subsurface. This area has been the subject of additional remedial investigation since 2008 based on both the documented history of use and the spatial and temporal trends in groundwater quality collected as part of the groundwater IRM (pumping and treatment system). This area, including the footprints of Buildings 16, 19, 22 and 23, coincides with the elevated soil and groundwater VOC data collected from 2008 to 2014 (see **Figure 8**). It represents a unique zone of recalcitrant VOC mass in soil and groundwater that has been adequately delineated and that will be addressed as part of the proposed soil and groundwater remedial measures.

Buildings #10/#18 Boiler Room & Transformers: Historically, this area contained boilers and transformers. The area was initially assessed by soil sampling during the 1995 RFI (Ciba, 1995). To evaluate current soil and groundwater conditions, additional data were collected. TPH samples collected from the area were below screening levels and no impacts from the boilers appear to have occurred. Total PCBs were detected at a concentration of 71.8 ppm at a depth of 4-6 ft bgs, adjacent to the transformer area. These residual impacts will be addressed as part of the proposed soil remedial measures.

Building #24 Zinc Rail Car Area. Dry chemicals were loaded into rail cars at this location. Soil samples collected in 2012 did not contain zinc above RIDEM DEC screening levels nor do these samples contain other COCs. This area does not represent an ongoing data gap, and no further action is warranted.

Building #21 Zinc Sump: Soil samples were collected in 2012 to delineate zinc surrounding the zinc sump. Soil samples did not contain zinc above RIDEM DEC screening levels. However, a soil sample collected from 0-2 ft bgs contained 36.7 ppm total PCBs and another sample contained 19.3 ppm total PCBs. These detections are likely due to mechanical transport during facility demolition, for example from the area in and around buildings 10 and 18. These residual impacts will be addressed as part of the proposed soil remedial measures.

Building #21 Tank Farm: Historically, this was a tank farm that supported pharmaceutical manufacturing activities in Building #21. The data support the characterization that this area is at the northern edge of the residual impacts referenced for the Jet Sump Area, but that it was not a source for impacts currently observed. Thus, the area has been adequately delineated.

Piping Runs: The underground piping transported manufactured material from building to building on-Site. The only documented release from the piping was the toluene release at Building 11 in the 1980s (subject to the SVE IRM). PDI data collected in September 2014 shows that the extent of the impact from SWMU 11 has migrated south of the area remediated by the SVE and in the area of the piping run. The data show that the contaminants are primarily toluene and 2-chlorotoluene, but the other COCs with MPS are present as well. In addition to the VOCs, soil adjacent to the run is impacted by PCBs, but this is consistent with site-wide PCB impacts observed. COCs were detected in soil at the southern end of the run, which terminates in the Jet Sump impact area, and where 2-chlorotoluene, toluene, and chlorobenzene are detected above their respective MPS. The PCB and VOC impacts will be subject to remedial action.

Hot Sump: The Hot Sump was connected to the outfall to the river cofferdam water treatment area, where sediment impacts were delineated and removed during the Pawtuxet River IRM. Groundwater and soil data show that residual contamination is not present in this area. This area does not represent an ongoing data gap, and no further action is warranted.

Septic Tank: Based on historical information, the site previously utilized one septic system for sanitary wastewater disposal prior to Ciba building a wastewater treatment plant off-Site in 1975. The associated sewage tank is located to the east of Building 14. No soil or groundwater impacts in the vicinity of this area were apparent from 2012 sampling. The septic tank was found to be present and intact, and it will be properly abandoned during remediation of PCB impacted soil in the FPA.

UST Vault/Underground Tunnel: Former USTs and a below-ground vault located on the eastern portion of the production site were decommissioned according to BASF staff interviews, but no confirmatory sampling or closure reporting exists. Facility staff were able to find photo-documentation of the UST removal. Soil and groundwater samples collected adjacent to the former vault had no detections of Site COCs. The tunnel access was reportedly sealed and the tunnel filled with crushed building material during plant decommissioning. This area does not represent an ongoing data gap. No further action for this SWMU is warranted.

Loading Dock: Manufactured chemicals were shipped off-site from area. No spills or releases were documented to have occurred. Soil samples collected in 2012 were analyzed for metals, pesticides, VOCs, SVOCs, and PCBs. There were no detections above the RIDEM DEC levels. This area does not represent an ongoing data gap, and no further action is warranted.

AOC 13 - The main manufacturing area was considered an Area of Concern based on past operations and investigated in the 1995 RFI (Ciba, 1995). This area comprised the entirety of the FPA. Recent data gap investigations have focused on discrete areas within this AOC, as described in the sections presented above (i.e., Building 16/Jet Sump Area, Building #10/#18, Building #21, Building #21 Tank Farm, Hot Sump, Piping Runs, Building #24 Zinc Sump, MW-34D area).

Associated with the OWLA: Based on historical operation data, except for AAOI 15, the area north of the railroad spur that housed the plant's offices, laboratory, warehouse and parking was not considered an area of concern by the EPA. While this is the case, for completeness BASF identified this area for baseline sampling of soil, soil gas, groundwater and indoor air to verify this assessment.

AAOI 15 was identified during the RFI based on the presence of a laboratory sump and discharge piping that may have been used to dispose of waste. At that time, this area was discounted as a potential AOC because the sump area was sampled and no significant impacts were identified in the RFI. To verify this conclusion, investigation sampling in 2013 showed no elevated detections of VOCs, metals, pesticides or PCBs in this area. However, on the east side of building 15 near the sump location, two compounds, benzo(a)pyrene and dibenzo(a,h)anthracene were elevated above the RIDEM DEC levels for industrial/commercial use in shallow soil (0.5' bgs). These compounds are common in urban environments and the detections are likely attributable to vehicle exhaust particulate deposition and/or water runoff from paved surfaces. This area does not represent an ongoing data gap.

Additional soil sampling in the OWLA also showed no elevated detections of VOCs, metals, pesticides or PCBs in soil. However, as with AAOI 15, benzo(a)pyrene and dibenzo(a,h)anthracene were detected at elevated levels above the RIDEM Industrial/Commercial Direct Exposure Criteria (I/C DEC) in the former parking area (north of Buildings 20 and 26) and on the eastern side of Buildings 15 and 25. Total Petroleum Hydrocarbons (TPH) and other PAHs were also detected above I/C DEC in the former parking area. All the compounds detected are typical of urban impacts and are likely not associated with plant operations. These detections represent local impacts that will be addressed as part of this CMS.

Grab groundwater samples NP-GW1 and NP-GW2 had no detections of VOCs in groundwater.

While there was no indication of a release in and around the former office, lab and warehouse area (Buildings 15, 20, 25 and 26), soil gas results collected along the western side of Buildings 15 and 21 exceeded some EPA Vapor Intrusion Screening Levels for Soil Gas in residential areas. The compounds that exceed risk screening levels, chloroform and bromodichloromethane, are commonly related to drinking water treatment chemistry and are not deemed to be related to Site operations. Chloroform was not detected in groundwater samples collected from two groundwater grab sample locations in the vicinity of the Site buildings.

Sampling of soil vapor below and indoor air within the OWLA buildings in January 2014 indicate that chloroform and benzene are present in both soil vapor and indoor air at low levels though above the EPA stringent screening values. However, the detections in indoor air are within USEPA's target cumulative risk range of $1x10^{-6}$ to $1x10^{-4}$ and the total HI is below RIDEM/USEPA's target HI of 1, indicating that there is no unacceptable risk/hazard associated with inhalation of indoor air within the Site buildings. Chloroform and benzene may be associated with cleaning products (e.g., bleach) and/or laboratory uses where residual concentrations are slowly desorbing from building surfaces.

2.5.1 FPA Groundwater Characterization

The revised SRI report (AECOM, 2014) provides the details of the data presentation and derivation of the CSM for the Site, where the CSM provides an explanation for the nature and extent of contamination observed, and it provides the basis to propose necessary and sufficient remedial action(s) to address potentially unacceptable risk to human health and the environment.

Since the completion of the revised SRI report, PDI data collection has been completed in areas of the FPA. The PDI data was collected after identifying elevated VOC concentrations in vadose zone soils within the SWMU 11 area (E-280 and E-300) where a historic toluene release was documented and/or localized impacts from the piping runs may have occurred. Four soil borings were advanced via Geoprobe direct push methods south of the elevated VOC concentration area. Soil was sampled from the ground surface into shallow to mid depth groundwater (to approximately 26 ft bgs) at SB-301, SB-302, SB-303, and SB-304 to determine whether VOC impacts are present in the vadose zone and/or groundwater via a pathway from upgradient shallow soil impacts to downgradient groundwater. Two soil samples were collected and analyzed for VOCs from each soil boring at intervals exhibiting high field screening levels of VOCs (based on PID readings). In addition to soil, each soil boring was completed with temporary piezometer monitoring points screened from 6 to 16 ft bgs and 16 to 26 ft bgs. Groundwater was sampled from each monitoring point and analyzed for VOCs. Procedures for soil and groundwater collection were consistent with those described in the Supplemental Remedial Investigation (SRI) Workplan (AECOM, June 2012).

What follows here are the elements of the CSM upon which this CMS is based. The hydrogeological attributes of the CSM are as follows:

- Groundwater is encountered at 6 to 10 ft bgs.
- The water table gently slopes toward the river (**Figures 4A** and **4B**).

- The vertical gradient is generally downward across the Site indicating that groundwater recharge conditions prevail (**Figure 4A** and **4B**).
- The natural discharge point for site-related groundwater is the Pawtuxet River, which is a gaining water body adjacent to the Site, as evidenced by the fact that the river stage is lower than the groundwater elevation (**Figure 4A** and **4B**).
- The groundwater flow is affected by a bulkhead wall (sheet piling) that extends to a depth of 25 ft bgs, where groundwater is deflected downward under the wall as it migrates toward the river (**Figure 4A** and **4B**).
- Hydraulic and water quality profiling conducted along the southern property boundary and along the bulkhead abutting the Pawtuxet river indicates that the intermediate "aquitard" is heterogeneous with permeable layers containing contaminant mass, and likely providing a conduit to flow and transport of Site COCs.

The nature and extent of contaminant mass in groundwater is described by the following CSM:

- Residual groundwater impacts are limited to the southwestern quadrant of the Production area, and they are associated with past plant operations that occurred primarily in Building 16. Building 16 was associated with a former sump leak. PDI data collected in September 2014 also show residual soil and groundwater impacts associated with SWMU 11 and potentially from portions of the piping run in the vicinity of SWMU 11.
- The impact observed is primarily composed of the five VOC COCs commonly used in the production process, identified in 1995 and assigned MPS, namely: 1,2-dichlorobenzene, chlorobenzene, 2-chlorotoluene, toluene, and total xylenes. **Figures 10A-J and Figures 11A-E** present the groundwater plumes in plan and cross-sectional views for each of the five site-specific COCs which have MPS defined.
- In addition to the 5 VOC COCs listed above, there is a sub-area where other VOCs are uniquely identified as exceeding the RIDEM GB criteria. These include: tetrachloroethene, vinyl chloride and benzene. These compounds are not detected in on-site soil at elevated concentrations and no likely source material based on past operational history. These non-MPS VOC detections are observed in groundwater only and at elevated concentrations adjacent to the river and the neighboring facility. It is possible that the source of these VOCs is off-site. Nevertheless, these compounds are generally collocated with one or more site-related COCs in excess of an MPS.
- The volume of aquifer impact is defined by any compound exceeding the MPS. Thus the remedial action target volume is defined by the MPS.
- The shallow VOC COC plume extends to the bulkhead wall. It is likely that these compounds/impacts have migrated along the permeable shallow aquifer/less permeable intermediate aquifer interface.
- Groundwater impacts are more extensive with depth (> 20 ft) due to a combination of influences: downward flow (general recharge conditions enhanced by the bulkhead), dispersion induced by aquifer heterogeneity, and historical remedial pumping [PW-120 screen 10 to 15 ft bgs and 30 to 40 ft bgs and PW-130 screen 7 to 17 ft bgs and 28 to 38 ft bgs])
- The intermediate aquifer zone (approximately 20-30+/- ft bgs) consists of heterogeneous low permeable materials with lenses of higher permeability that contain VOC COC impacts above the MPS.

- Water quality sampling of the aquifer on both the upland and river sides of the bulkhead wall shows VOC COC impacts above the MPS. Therefore, a completed exposure pathway is apparent.
- The nature and extent of COC impacts are consistent with the characterization of plant operations, the hydrogeology (i.e., aquifer heterogeneity and groundwater flow) and the location of potential VOC source material.
- PCBs were detected in upland groundwater within the VOC MPS exceedance zone. The only available standard for PCBs in groundwater is the RIDEM drinking water maximum contaminant level (MCL) of 0.5 ug/L. PCBs were detected in groundwater above the MCL in samples collected from MP-3I and MP-3S during July 2013. These wells were installed in 2012 as part of the AVE/AS pilot test. Where PCBs were detected in groundwater, one sample (MP-3I, 18-22 ft bgs) had an elevated turbidity (538 NTU) and a second sample (MP-3S, 5-13 ft bgs) had low turbidity (2.9 NTU). PCBs could be sorbed to soil particles or dissolved in water at low concentrations with co-solvents, or these detections may be due to carry down during well installation. PCB concentrations are not detected in groundwater in other parts of the upland area (MW-21S, MW-34D, MW-102D) and these PCB concentrations at MP-3 attenuate in groundwater as groundwater migrates to the river (MW-2S) and are not detected in other wells along the river (MW-31S, MW-31D, MW-29D, P-30D, P-35S). While PCBs exceeded the drinking-water standard at two upland locations (9 ug/L and 14.1 ug/L), the GB aquifer is not used for drinking water. Given this fact and the proposed remedial measures for PCB soil impacts (removal and capping) and MPS groundwater impacts (in-situ treatment) (**Figure 8**), these impacts do not require targeted remedial action.

2.5.2 FPA Soil Characterization

As detailed in the SRI Report (AECOM, 2014) and outlined here, there are areas of residual PCB, TPH/SVOC, and VOC mass present in soil within the FPA:

- VOC mass potentially capable of impacting groundwater above the MPS was detected in vadose zone soils (2-6 feet bgs) collected in the southwest corner of the former Building 11 footprint, where the soil stabilization SVE IRM was implemented from 1997 to 2005 (see **Figures 10A-J, and Figure 11A-E** for location). Additional PDI data collected in September 2014 indicates that the vadose zone soils have impacted shallow and deep groundwater in this area.

The nature and extent of the residual PCB mass in soil within the FPA includes:

- PCB impacts associated with soil samples analyzed during the Supplemental RI appear to be related to spills or operational activities at Buildings 10 and 18, where transformers were once used, as well as potentially with a supply line or disposal line related to Building 11 operations. The general distribution across the FPA is consistent with mechanical mixing that likely occurred during plant demolition. These impacts are proximal to the PCB soil excavations that were conducted during the IRM (**Figure 3**).
- PCB grid sampling conducted during 2013/2014 fully characterized the extent of the PCB impacts located at the Site. While limited PCB impacts had been characterized and thought to have been remediated with IRM excavation events, several areas exceeding the 50 ppm MPS and 10 ppm RI DEM I/C and residential DEC remain. The areas with elevated PCB concentrations are illustrated on **Figure 9**.

2.5.3 OWLA Soil Characterization

Elevated TPH and SVOCs were identified above I/C DEC and/or R DEC in shallow soil sampled in the parking area to the north of the Site buildings and SVOCs above I/C DEC were detected east of the Site buildings. While these compounds were not identified as COCs for the Site, their nature and extent will be used to define necessary remediation and future land use options. The compounds and exceedances are illustrated on **Figure 12**. Several soil samples in the northern area were also analyzed for PCB (SB-128, SB-129, SB-144 through SB-149) and were less than 1 ppm.

2.5.4 Pawtuxet River Sediment

As discussed in Section 2.4.2, a sediment IRM was implemented in 1996 to address site-related impact to this medium (Sediment IRM Pawtuxet River, 1996). The IRM continues to rely on a clean sand cap to sequester deeper site-related impacts that remain. The last time the cap integrity was characterized was in 2011 after a 100 year flood event, and at that time the cap was shown to be intact and functioning as intended (AECOM, 2011).

2.6 Status of the FWWTA

The FWWTA property was sold in 2004, and since that time it has been used as a commercial landscaping business. As introduced previously, to date the USEPA has not issued a Statement of Basis and as such it remains part of this CMS.

A remedial investigation was conducted at the FWWTA from 1990 to 1995 and described in the RFI report (Ciba, 1995). Two SWMUs (10 and 12) were associated with the FWWTA, described in the RFI (Ciba, 1995) and are illustrated on **Figure 13.**

RFI soil data from the FWWTA was evaluated in a risk assessment submitted to and reviewed by USEPA (RFI, 1995). There were sporadic detections of two SVOCs, a pesticide (chlordane) and arsenic in soil in excess of the RIDEM I/C DEC, as shown in the following table. Except for chlordane which was utilized on-Site for pest control, these compounds were not considered site-related at the time of the RFI.

Table: FWWTA Shallow Soil Detections Exceeding I/C DEC

Compound	I/C DEC (ppm)	Concentration (ppm)	Sample Depth (ft bgs)	Frequency of Detection
Benzo(a)pyrene	0.8	3.6	0.5 – 2	5 of 18
Dibenz(a,h)anthracene	0.8	17	0.5 – 2	1 of 18
Chlordane	4.4	4.6 J	0.5 – 2	8 of 21
Chlordane	4.4	19 J	0 – 2	8 of 21
Arsenic	7.0	8.1 J	0.5 - 2	15 of 15
Arsenic	7.0	11.7	0.5 - 2	15 of 15
Arsenic	7.0	8.2	0.5 - 2	15 of 15
Arsenic	7.0	7.7 J	0.5 - 2	15 of 15
Arsenic	7.0	9.5 J	0.5 - 2	15 of 15
Arsenic	7.0	9.9	0.5 - 2	15 of 15

*Frequency of detection indicates how many soil samples in which the compound was detected, and any exceedances of I/C DEC are listed in the table (see **Figure 13** for location).

The risk assessment concluded that detected compounds identified as FWWTA compounds of potential concern (dieldrin, chlordane, 2,3,7,8-TCDF, bis(2-ethylhexyl)phthalate, PCBs) posed no unacceptable risk for an unrestricted future site use because the risk was within the USEPA target risk range of 1×10^{-4} and 1×10^{-6} and the total hazard index was less than 1.

In addition to the conclusion of the risk assessment for unrestricted use, there are development constraints on the property. **Figure 13** shows that the sporadic I/C DEC exceedances are within the 200-foot riverbank wetland zone, which precludes any development and soil management without RIDEM approval. Additional approval would likely be required by the municipality for work in the 100 year floodplain and depending on the size of any future project, RIDEM involvement may be necessary as well if the disturbance exceeds certain land area thresholds. These permit applications would require a stormwater management and sediment and erosion control plan, approval of which may offer a means to limit exposure to impacted soil. The property is currently zoned as commercial for office or neighborhood business (Cranston, RI Code of Ordinances, library.municode.com). Based on the limited risk and development constraints, the FWWTA soil does not warrant further action.

Groundwater sampling in the FWWTA (Ciba, 1995) was also evaluated in a risk assessment, which was submitted and reviewed by USEPA. The risk assessment concluded that compounds detected in groundwater posed no unacceptable risk for an unrestricted residential future site use. In addition, groundwater did not exceed any criterion listed in the Remediation Regulations. Therefore, the groundwater at the FWWTA property does not warrant further action.

3.0 Corrective Measures Objectives

Corrective Action Objectives (CAOs) provide the basis for remediation and summarize the remedial goals for corrective measures. CAOs were developed for the following areas:

1. Soil areas: Residual PCB impacts in the FPA and shallow soil in the OWLA (adjacent to buildings and in the former parking area);
2. Groundwater in the southern portion of the FPA;
3. Sediment in the Pawtuxet River adjacent to the FPA; and
4. Soil in the FWWTA.

Site-wide and media-specific CAOs are summarized below:

- *Site wide CAO*
  - Protection of human health from unacceptable exposure (unacceptable is defined as cancer risk greater than 1 x 10^{-4} and Hazard Index > 1) to environmental impacts at the Site.
  - Protection of the environment from exposure to impacts at the Site.
- *FPA CAOs*

  Soil
  - Ensure soil is remediated to a direct exposure level that is protective of human health for anticipated high occupancy, industrial, commercial and open space future uses.

  Groundwater
  - Maintain compliance with regulatory consent orders and RCRA Corrective Action.
  - Reduce groundwater impacts by addressing identified residual impacts acting as ongoing sources.
  - Reduce FPA groundwater impacts to below applicable standards as described in **Section 3.1**.
  - Reduce impacts to the Pawtuxet River sediment by treating groundwater transported in permeable pathways in the vicinity of the bulkhead wall, such that COC concentrations in shallow and deep groundwater potentially discharging to the river are below applicable criteria.
- *OWLA CAOs*

  Soil
  - Ensure soil is remediated to a direct exposure level that is protective of human health for industrial and commercial future uses.

- *River Sediment CAOs*
  - Ensure existing sediment cap integrity is protective of the environment through periodic monitoring.
- *FWWTA CAOs*

  Soil
  - Ensure current and future land uses are consistent with historic risk evaluations, and future uses are protective of human health.

3.1 Media Specific Cleanup Standards

The Rhode Island Remediation Regulations (Remediation Regulations [RIDEM, 2011]) and site-specific Media Protection Standards (MPS) provide the applicable clean-up criteria for soil and groundwater at the properties under the RCRA Corrective Action program. The criteria to be applied for various media at the properties are discussed in the following sections..

3.1.1 FPA Soil

The Remediation Regulations contain numerical, default, criteria used to determine the need for remediation of soil associated with a release that are based on both the potential for human health impacts from direct exposure to contaminants in soil (direct exposure criteria) and on the potential for contaminants in the soil to have an adverse impact on groundwater (leachability).

Direct exposure criteria are specified based on the assumption that only industrial and certain commercial and open land use scenarios will be permitted. Because the property is currently zoned industrial/commercial, it is assumed herein that future site use will not include residential, and this condition will be incorporated into the property deed in the form of an ELUR.

Because groundwater is classified by RIDEM as GB (not for potable use), RIDEM GB leachability criteria for the protection of GB groundwater quality apply.

Table 3 summarizes applicable numeric criteria for Site COCs in soil.

Direct Exposure Criteria

I/C DEC will be applied to the FPA, which is currently zoned industrial. Because the I/C DEC will be applied, an ELUR must be executed to preclude future residential uses of the Production Area.

According to the Remediation Regulations, I/C DEC may be applied to a depth of at least 2 feet below ground surface for each hazardous substance in soil if all of the following conditions are met:

a. The contaminated-site is currently limited to industrial/commercial activity. Open space provisions may be allowable under certain conditions with a clean 2 foot cap;
b. Access to the property containing the contaminated-site is limited to individuals working at or temporarily visiting the subject parcel;
c. The current and reasonably foreseeable future human exposure to soils at the contaminated-site is not expected to occur beyond a depth of 2 feet below ground surface; and

d. An environmental land usage restriction consistent with Rule 8.09 (Institutional Controls) is in effect with respect to the property, or to the portion of the property containing the contaminated site; such an environmental land usage restriction shall ensure that the property or restricted portion thereof is not used for any residential activity in the future and that any future use of the property or restricted portion thereof is limited to industrial/ commercial activity or RIDEM-supported open space.

Part (c) above is accommodated during future potential site redevelopment by the development and use of an appropriate soil management plan to be incorporated into an ELUR that specifies means and methods to protect worker health during and after construction. Part (d) must remain in place until further cleanup or evaluation is performed to meet more stringent criteria for unrestricted re-development. These conditions are incorporated into this CMS.

These criteria are for comparison to soil data, and **Table 3** provides the I/C DEC for the applicable site soil COCs (i.e., PCBs).

Leachability Criteria

Because the Production Area is located in a GB groundwater area, the GB leachability criteria, or equivalent as defined in the Remediation Regulations, apply. **Table 3** provides the relevant criteria for the applicable site soil COCs (i.e., PCBs).

Site-Specific Media Protection Standards (MPS)

Site-specific soil MPS were developed for the Production Area soil in the RFI (Ciba, 1995). A Public Health and Environmental Risk Evaluation (PHERE) was performed (Ciba Corporation, 1995), and no unacceptable human or ecological health risk was found for soils. While this was the case at the time, the site-specific PCB MPS for the Production Area soil was set at 50 ppm based on consideration of a future outdoor worker for an industrial or commercial land-use scenario. The site-specific MPS is compared to current federal and state rules governing PCB cleanup. Specifically, under the Toxic Substance and Control Act (TSCA), 40 CFR 761.61(a)(4), the low occupancy[1] criteria is 50 ppm if the site is fenced and marked. ~~less than or equal to 100 ppm PCBs may be left on Site with a cap covering the Site along with a low-occupancy future Site use restriction[1].~~ Alternately, removal of all PCBs in soil greater than 10 ppm and a cap over soil that contains greater than 1 ppm would allow a high occupancy Site re-use[2]. Finally, an unrestricted use scenario is allowed with no capping requirement if PCBs are remediated to a level less than 1 ppm. The Rhode Island (RI) I/C DEC rules for PCBs in soil include removal of all PCBs greater than 10 ppm and placement of a 2 ft soil cap to support a high-occupancy, industrial/commercial future use scenario, or RIDEM-supported open space. The RIDEM requirements allow for the scenario evaluated herein consisting of the use of the 2 ft soil cap over soil with less than 10 ppm PCBs. An unrestricted use scenario was also considered

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[1] Low occupancy refers to areas where people do not spend significant amounts of time (e.g. unoccupied area outside a building

[2] High occupancy refers to areas where people spend significant time, 840 or more hours per year without dermal or respiratory protection (e.g. schools, residences).

to provide greater future use flexibility. PCBs must be remediated to a level less than 1 ppm in the unrestricted use scenario.

Caps used as remedial measures under TSCA 40 CFR 761.61(a)(7) are required to meet permeability, sieve, liquid limit and plasticity requirements. Variation from these requirements will require approval from EPA. In areas where PCBs will remain on-site at concentrations between 1 and 10 ppm, the RIDEM remediation regulations require that contact with such soil be eliminated by rendering it inaccessible beneath 2 ft of clean soil with no permeability requirement as 10 ppm meets the RIDEM GB leachability requirement. A clean soil cap of 2 ft also meets the minimum thickness requirements (10 inches) required by TSCA 40 CFR 761.61(a)(7). This RIDEM-based measure to render the soil inaccessible is an effective means of compliance with the DEC when the soil cap is maintained through implementation of an ELUR that details the configuration of the inaccessible soil area and requires that the cover be maintained. Therefore, a RIDEM cap is considered a feasible alternative to that required under TSCA 40 CFR 761.61(a)(7).

3.1.2 FPA Groundwater

Site-related groundwater is classified by the RIDEM as GB, which is not suitable for use as a current or potential source of drinking water. The Remediation Regulations contain numerical, default criteria for contaminated GB groundwater associated with a release area. The criteria are established to be protective of human health (from contaminants that may volatilize from contaminated groundwater) and the environment (from contaminants that may adversely affect surface water resources). Additional information on groundwater criteria is presented in the following sections. **Table 4** summarizes applicable numeric criteria for Site COCs in groundwater.

GB Groundwater Objectives

The Remediation Regulations specify criteria for the protection of groundwater in a GB groundwater area. As discussed in Section 2.5.1, chlorinated ethenes and benzene have been collocated with Site COCs in groundwater. These compounds will thus be addressed with the remedy selected.

Site-Specific Media Protection Standards (MPS)

The Pawtuxet River Corrective Measures Study (Woodward-Clyde, 1996) presented MPS for site-specific volatile organic compounds (VOCs) in groundwater at the Production Area property: toluene (1,700 ppb), 2-chlorotoluene (1,500 ppb), 1,2-dichlorobenzene (94 ppb), chlorobenzene (1,700 ppb), and total xylenes (38 ppb). The MPS for these COCs, except toluene, were based on benthic invertebrate Toxicity Reference Values (TRVs) and developed to be protective of benthic organisms as site-related groundwater discharges to the river. For toluene, the MPS was based on the RI GB Groundwater Objective because it was a lower value, and thus, more protective. The MPS for total xylenes was later corrected to 76 ppb in the April 1998 Groundwater Sampling Report submitted to USEPA in August 1998. The report states that the revision, based on a mis-reporting of 38 ppb in the original Pawtuxet River CMS, was approved by USEPA. These groundwater MPS will be applied to the Production Area property.

3.1.3 OWLA Soil

As discussed in Section 2.5, the OWLA was not identified as an AOC, 2013 – 2014, sampling by BASF detected sporadic PAH and SVOC compounds that exceed the RIDEM I/C and R DEC. As such, for any future land use scenario these soils will need to be addressed by eliminating the direct potential exposure pathway (removal and/or clean cover) and imposition of an ELUR that will preclude future residential use.

3.1.4 Pawtuxet River Sediment

As part of the Production Area IRM program implemented in the 1995 – 1996 time-frame, a voluntary sediment IRM was conducted, where over 2,225 tons of visually contaminated river sediment from the Former Cofferdam were excavated and replaced with a clean sand cap (Woodward-Clyde, 1996).

A major flooding event occurred during the spring of 2010, and at that time the USEPA requested that BASF re-sample the sediment cap to ensure that it is functioning as intended. In 2011 BASF took samples of the capped area and found it to be functioning as intended with the coarse sand cap still in place (AECOM, 2011).

This media is included in the CMS in order to specify a periodic monitoring program for the emplaced sand cap in the Pawtuxet River. **Table 5** outlines the periodic monitoring strategy for the cap and sediment.

3.1.5 FWWTA Soil

As discussed in Section 2.6, soil sampling in the FWWTA was evaluated in a risk assessment submitted to and reviewed by USEPA (RFI, 1995). The risk assessment concluded that compounds detected in soil posed no unacceptable risk for an unrestricted future site use because the risk was within the USEPA target risk range of 1 x 10^{-4} and 1 x 10^{-6}. This property is zoned as commercial for office or neighborhood business (Cranston, RI Code of Ordinances, library.municode.com) which is a more conservative re-use scenario than the risk assessment assumption of an unrestricted future use. Therefore, soil criteria will not need to be considered for the FWWTA. Based on redevelopment constraints due to the 200 ft Riverbank Wetland boundary and limited exposure risk, no further action is warranted for FWWTA soil.

3.2 Compliance Points

3.2.1 Soil

Soil compliance is point-by point, where the remedy must address all impacts above some standard either by removal, capping or imposing institutional controls. Post-remedy controls must be verified with an appropriate sampling plan. Post-excavation compliance sampling will be conducted as the soil remedy is implemented in the FPA. The compliance sampling program will be described in the future soil remediation design.

3.2.2 Groundwater

Site-related groundwater from the FPA eventually discharges to the Pawtuxet River. The MPS defined for the FPA were derived to be protective of environmental receptors, in particular benthic organisms. Thus, the compliance points for groundwater associated with the Production Area will be located between the Site and the river. Based on where the groundwater plume is located as it migrates towards the Pawtuxet River, the proposed wells where compliance with the MPS is needed for the Production Area are listed in the following table and shown on **Figure 14**:

Groundwater

MW-32S/D (Proposed)

MW-31S/31D

P-30D

MW-29D

3.2.3 Sediment

The sediment area that comprises the former cofferdam area, adjacent to the Production Area, will be addressed through periodic monitoring to confirm the presence of the IRM engineered control (i.e., sand cap). The area of the cap is depicted on **Figure 15**. A sediment cap monitoring program will be developed and submitted under separate cover.

3.3 Description of Remedial Alternatives Considered

3.3.1 FPA Soil

Remediation area limits for FPA soil vary based on the nature and extent of PCB impacts and potential future Site use scenarios which are presented below. In addition there are impediments to excavation in the form of foundations, footings and concrete rubble-filled basements. Soil volumes and areas presented below are based on existing data and provide a basis for alternative evaluation as potential remedial scenarios. Actual parameters may change based on either a pre-design investigation or post-excavation verification sampling, which may change the total estimated volumes for excavation, disposal or reuse in each scenario presented.

Low Occupancy Reuse Scenario - >50 PPM PCBs

The PCB MPS for the FPA soil is set at 50 ppm based on consideration of an outdoor worker for an industrial or commercial land-use. This cleanup level would allow a low occupancy Site re-use under current TSCA regulations. The low occupancy criteria is 50 ppm if the site is fenced and marked. Depth and areas associated with remediation of this potential future use scenario are shown on **Figure A-1.** The following aspects are associated with an excavation and capping remedy:

- Excavation/disposal: Several discrete areas of soil with PCBs > 50 ppm up to 6 ft deep, totaling 1,170 cubic yards (CY). In addition, as discussed in Section 2.5, the local VOC impacts associated with sample locations E300 and E280 will also be removed in this scenario (approximately 30 CY);
- Excavation/on-site reuse/consolidation/cap preparation of soil with PCBs > 1 ppm from the top 2 ft outside of the area to be capped (1,230 CY for on-site reuse);
- Clean cap material: Covers the Site with a 2 ft thick soil cap (5350 CY); and
- An ELUR and soil management plan are required for the FPA to ensure land use restrictions and cap maintenance.

The areas/volumes above involve discrete removal of soils with greater than 50 ppm PCBs. Details of area and depth calculations are included in **Appendix B**. A 2 ft clean soil cap would be utilized across approximately 3.1 acres of the FPA, but will require cap preparation excavations since a portion of the Site is located within the 100 year flood plain and raising the grade within the flood plain is not appropriate. The exact location and quantities of the cap over remaining material left on-Site would be determined during the design phase of work.

High Occupancy Reuse Scenario - >10 PPM PCBs

Removal of PCBs in soil greater than 10 ppm and a cap over soil that contains greater than 1 ppm and less than 10 ppm PCBs would allow a high occupancy Site re-use. Rhode Island (RI) I/C DEC limit PCBs in soil to a maximum of 10 ppm, with a 2 ft clean soil cap. Depth and areas associated with remediation of this potential future use scenario are shown on **Figure A-2**. The following aspects are associated with an excavation and capping remedy:

- Excavation/ off-site disposal: 6,300 CY from discrete areas of soil with PCBs >10 ppm to depths of up to 7 ft deep, this includes approximately 30 CY of residual VOC-impacted soil;
- Excavation/on-site reuse/consolidation/cap preparation of soil with PCBs >1 ppm from the top 2 ft outside the area to be capped: 3,800 CY (for on-site reuse);
- Backfill materials: 7,550 CY;
- Clean cap material: Covers the Site with a 2 ft thick soil cap (1,550 CY); and
- An ELUR and soil management plan are required for the FPA to ensure land use restrictions and cap maintenance.

The areas/volumes above involve removal of soils with greater than 10 ppm PCBs. Details of area and depth calculations are included in **Appendix B**. A 2 ft clean soil cap would be utilized across approximately 0.5 acres of the former Production Area, but will require cap preparation excavations since a portion of the Site is located within the 100 year flood plain and raising the grade within the flood plain is not appropriate. However, the exact location and quantities of the soil removed, reused, and the cap over remaining material left on-Site would be determined during the design phase of work.

Unrestricted Use Scenario - >1 PPM PCBs

An unrestricted use scenario was also considered to provide greater future use flexibility. PCBs must be remediated to a level less than 1 ppm in this case. Depth and areas associated with remediation of this potential future use scenario are shown on **Figure A-3**. The following aspects are associated with an excavation and capping remedy:

- Excavate: 11,000 CY from discrete areas of soil with PCBs >1 ppm to depths of up to 7 ft deep, this includes approximately 30 CY of residual VOC-impacted soil;
- Dispose: 16,750 CY;
- Re-use: 900 CY; and
- Backfill materials: 13,200 CY.

The areas/volumes above involve removal of soils with greater than 1 ppm PCBs for an unrestricted future use scenario. Details of area and depth calculations are included in **Appendix B**. No capping or ELUR and soil management plan would be required.

3.3.2 OWLA Soil

Remediation area limits for OWLA soil vary based on the nature and extent of PAH and SVOC impacts in excess of the RIDEM I/C DEC to support a nonresidential reuse scenario.

East of Site Buildings

Discrete areas of impacted soil will be addressed as follows on the east side of the Site buildings to prevent exposure to surface soil and attain compliance with I/C DEC:

- Surface soil (6 inches or greater in depth) will be removed;
- A witness marker barrier (geotextile and orange snow fence) will be laid down within the excavation;
- Clean soil will be imported and placed in the excavation;
- Grass and shrubs will be planted over the disturbed area;
- A fence may be installed around the area;
- An ELUR restricting future site use will be utilized; and
- A soil management plan will be developed to include: procedures for soil characterization, soil handling, storage/stockpile management, documentation of soil disposal, and a description of any institutional controls in place.

An outline of the area to be addressed is shown on **Figure A-4.**

Three Parcels North of Site Buildings

Three parcels are located north of the former laboratory and warehouse buildings that were historically used as parking areas for the facility. These three parcels are located adjacent to residential properties. Because the soil below the pavement is impacted with PAH and SVOC above the I/C DEC, to comply with the Remedial Regulations an ELUR will be required that specifies future non-residential use and maintenance of the pavement surface. In addition, a soil management plan will be included to address the scenario where the pavement is removed. Targeted excavation may be utilized to address soil containing I/C DEC exceedances in this area. The area to be addressed is shown on **Figure A-4.**

3.3.3 FPA Groundwater

Remediation area limits were selected to achieve the MPS criteria of Site COCs identified as discharging to the Pawtuxet River. Additional contaminants exceeding GB groundwater criteria are located within the COC treatment area and will thus also be addressed.

The extent of groundwater requiring remediation was evaluated using plans of the Site, groundwater flow mapping, groundwater analytical data and cross-sections of subsurface conditions. Cross-sections were constructed parallel and perpendicular to the approximate axis in the direction of groundwater flow. The horizontal extent of VOC impacts to groundwater is depicted on **Figure 8.** Areas highlighted on the figure represent MPS exceedances. In addition to illustrating the distribution of MPS exceedances, the conceptual groundwater remedial approach is depicted on **Figure 16**.

The available data were integrated and combined to identify the appropriate treatment zones, i.e., permeable media with COC impact. Cross-section A – A' (parallel to plume axis) is included as **Figure 17**. Electrical resistivity data was contoured and plotted on this cross section as is the MPS exceedances distribution. Electrical resistivity in this aquifer is correlated with more permeable materials, because fine-grained materials like silts/clays are generally more electrically conductive (or, have lower electrical resistivity). **Figure 17** is illustrative of the highly heterogeneous subsurface.

The stratigraphic and groundwater analytical data were evaluated to determine the volumetric zones where remediation would be required and most effective at addressing groundwater impacts and achieving the remedial objective. **Figure 17** includes the treatment intervals that result from this evaluation.

Because of the depth of impact and the presence of subsurface infrastructure left in place during plant demolition (i.e., foundations), only in-situ contaminant mass destruction technologies or groundwater containment are feasible alternatives.

The mass destruction technologies include in-situ biotic degradation and in-situ abiotic chemical oxidation (see Section 4.2.2). Active treatment will focus on breaking the transport pathway from upland FPA groundwater reaching the Pawtuxet River sediments and surface water and removing residual source material in upland portions of the FPA.

3.3.4 Pawtuxet River Sediment

The former cofferdam area within the Pawtuxet River that was capped during a historic IRM represents the limits considered for a periodic monitoring program.

3.3.5 FWWTA

The FWWTA has sporadic I/C DEC exceedances of several PAHs, a pesticide (chlordane) and arsenic (a naturally occurring metal). These detections are located within 200' of a wetland bank, a condition that precludes land development and soil management without RIDEM approval and while not explicitly an ELUR, does give some jurisdiction to RIDEM over development. Further, depending on the size of a future development scenario, additional municipal/RIDEM permitting may be required to address stormwater management and sedimentation and erosion controls during construction because portions of the FWWTA are within the 100 year floodplain and designated floodway of the Pawtuxet River. This condition, coupled with the conclusion of a human health risk assessment that supported unrestricted land use, is consistent with a no further action scenario.

4.0 Screening of Technologies

4.1 Screening Criteria

An initial list of potential technologies was screened for impacted media at the Site. Criteria used to screen technologies include site conditions, contaminant characteristics, and technology characteristics. A description of each criterion is provided.

- **Site conditions**: Site data was reviewed to identify conditions that may limit or promote the use of certain technologies. Technologies whose use is clearly precluded by site characteristics were eliminated from further consideration.
- **Contaminant characteristics**: Identification of contaminant characteristics that limit the effectiveness or feasibility of technologies is an important part of the screening process. Technologies clearly limited by these contaminant characteristics were eliminated from consideration. Contaminant characteristics particularly affect the feasibility of in situ methods, direct treatment methods, and land disposal (on/off site).
- **Technology limitations**: During the screening process, the level of technology development, the performance record, and the inherent construction, operation, and maintenance limitations were identified for each technology considered. Technologies that are unreliable, perform poorly, or are not fully demonstrated for the Site conditions and COCs were eliminated in the screening process.

Technologies which are deemed impracticable for use at the Site based on site conditions and contaminant mixtures were not retained for further evaluation.

4.2 FPA Remedial Technologies

The screening of the soil and groundwater technologies considered for the Production Area parcel is discussed below.

4.2.1 FPA Soil Technology Screening

Soil in the FPA contains elevated concentrations of total PCBs that exceed the RIDEM I/C DEC concentration of 10 ppm as well as isolated locations that exceed Toxic Substances Control Act (TSCA) limits and the site-specific MPS of 50 ppm. In addition, sporadic detections of semi-volatile organic compounds (SVOCs) and VOCs at concentrations that exceed RIDEM I/C DEC are present. Remediation of impacted soil is evaluated in the CMS. Alternatives under consideration are: No Action, Institutional and Engineering Controls, ELUR, Engineered Control (Cap), Excavation and Off-Site Disposal. Combinations of these alternatives are evaluated. Initial screening results for soil are included in **Table 6**. Figures showing conceptual remedial designs, soil volume calculations, and costs/assumptions in implementation are included in **Appendix A, Appendix B, and Appendix C** respectively. Retained technologies are further described in the following sections.

4.2.1.1 No Action

The no action technology serves as a baseline against which other corrective measure technologies can be compared. Under this alternative, no remedial action would be conducted. The contaminants are left in place without implementing any containment, removal, treatment, or other mitigating actions. The no action alternative would not include institutional or engineered controls to prevent access to surface or subsurface soils. No ongoing monitoring is included with this alternative.

4.2.1.2 Institutional Controls

Institutional controls are used to reduce risk of human exposure and/or further impacts to the environment by restricting site use and/or rendering impacts inaccessible or environmentally isolated.

Land use restrictions are means of enforcing a restriction on the former Production Area that limits exposure to impacted materials and prevents actions that would interfere with the remedial program. The former Production Area is zoned industrial/commercial and currently is idle. The former Production Area will continue to meet the requirements of industrial-commercial land use in the future, and an ELUR limiting future use to industrial-commercial use will be recorded, unless further cleanup or evaluation is performed to meet more stringent criteria for residential re-development. There are three general types of ELURs for soil, which are described below:

- Limits future uses of the former Production Area to industrial-commercial;
- Prohibits disturbance or exposure to inaccessible soils (e.g. impacted soil below an adequate separation layer); and
- Protects any engineered controls that prevent infiltration of water through impacted soil.

The three ELURs allow for access to the former Production Area to implement required monitoring.

In some cases, the ICs are used in conjunction with a containment mechanism (e.g. capping/engineered control) to address applicable criteria. ICs were retained for evaluation.

4.2.1.3 Engineered Controls

Engineered controls are used to reduce risk of human exposure and/or further impacts to the environment by rendering impacts inaccessible or environmentally isolated.

The existing engineering controls at the Production Area consist of perimeter fencing around the Site to prevent unauthorized access, and paved areas which inhibit direct contact with underlying soil.

An engineered control cap prevents direct exposure to the contaminants and/or prevent migration of the contaminant. Engineered control caps include containment technologies consisting of covers and/or impermeable liners. Implementation of this remedial approach requires:

- Assessment of hydrogeologic setting (e.g., proximity to wetlands and flood hazard areas);
- Permitting;
- ELUR;
- Long-term monitoring and inspection/maintenance plans; and
- Annual reporting.

The use of engineered controls utilizing covers and/or impermeable liners to address DEC exceedances was retained for evaluation.

4.2.1.4 Excavation and Offsite Disposal, Containment or Reuse

Excavation of impacted soils will be evaluated to address I/C DEC exceedances in the former Production Area for PCBs and SVOCs. The following options were retained for evaluation:

- Excavation and off-site disposal; and
- Excavation and on-site consolidation/reuse beneath an engineered control.

Regarding implementability, recall that when the plant was demolished the subsurface structures were left in place including extensive foundations, footings and pilings. These concrete structures will to some extent limit excavation.

4.2.2 FPA Groundwater Technologies

The alternatives described in this section are applicable to FPA groundwater.

Several technologies presented in the Stabilization Report (Woodward-Clyde, 1996) have already been constructed in the former Production Area. These technologies include a soil vapor extraction (SVE) system, extraction wells (hydraulic control system), and technologies used to treat extracted groundwater. The SVE system was constructed and operated to treat a toluene spill; it was shut down in 2005. The groundwater extraction and treatment system operated from 1996 to 2010 when long-term monitoring data showed aquifer restoration complete except for a recalcitrant area that was the subject of extensive remedial investigation (AECOM, 2012), and the recalcitrant area is the subject of this CMS.

Initial technology screening results for groundwater are included in **Table 7**. Figures showing conceptual remedial designs and costs and assumptions in implementation are included in **Appendix D** and **Appendix E,** respectively. Retained technologies are further described in the following sections.

4.2.2.1 No Action

No action provides a comparative baseline against which other corrective measure technologies can be compared. Under this alternative, no remedial action would be conducted. The contaminants are left in place without implementing any containment, removal, treatment, or other mitigating actions. All groundwater monitoring, groundwater extraction, and reporting activities would cease. Natural processes such as biodegradation, dilution, and attenuation would continue, but these processes would not be monitored.

4.2.2.2 Institutional and Engineering Controls

Institutional controls are a means of enforcing a restriction on the Site that limits exposure to impacted materials and prevents actions that would interfere with the remedial program. The Site is currently idle. The Site will continue to meet the requirements of industrial-commercial site use; however, an ELUR limiting future use to industrial-commercial use has not yet been recorded for the Site. An ELUR limiting site use to industrial-commercial is anticipated, unless further cleanup or evaluation is performed to meet more stringent criteria for residential re-development.

Engineering controls consist of means to physically isolate residual source areas in soils and the impacted portions of the aquifer. A sheet pile wall installation around impacted soil and groundwater was considered in this alternative.

4.2.2.3 Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) is a technology that relies upon the reduction of contaminant concentrations in groundwater resulting from the combined effect of dispersion, diffusion, volatilization, sorption, abiotic degradation, and biodegradation. The combined effect of these processes results in a concentration reduction over space and time that will result in a restorative trend. MNA is a plausible corrective measure that also involves groundwater monitoring to confirm the effectiveness of the natural attenuation and to quantify the reductions. MNA may be incorporated as a component of the remedial approaches outlined below.

4.2.2.4 In Situ Treatment Technologies

Initial considerations were made for implementability of a plume-wide versus barrier approach for in situ treatment technologies. There are several site attributes that affect implementability. First, the recalcitrant groundwater impact zone that is the focus of the remedial action considered here is associated with contaminant releases that occurred more than 40 years ago. In addition, a soil vapor extraction (SVE) system operated in the SWMU 11 area as an IRM for 8 years to address a toluene pipeline release and a groundwater capture system was operated for 12 years as an IRM to address this impact by controlling groundwater discharge to river sediments and surface water (the identified receptor pathway). Locally, elevated concentrations of site COCs are present in a residual source zone in upland portions of the FPA. As the data support, in downgradient locations these conditions combine to result in the delineated recalcitrant mass occurring primarily as adsorbed and dissolved phase adjacent to and within the low conductivity aquifer material (silt). This mass is slowly back diffusing into the more permeable units to create the groundwater plume that is observed to be approaching the river today. An in-situ remedial action that attempts to address this entrained mass through amendment emplacement will need to be applied on a fine spatial scale owing to the low conductivity material characterizing the aquifer.

In addition to this fate and transport characterization attribute, one needs to consider a second key Site attribute, where the impact area is below and around former building foundations and footings and pilings that remain in place. These extensive concrete structures will significantly limit the ability to apply necessary amendments at the appropriate scale in terms of required spatial distribution and volume acceptance for a plume-wide approach.

Given these attributes, a barrier approach was carried forth as the most feasible treatment application for breaking the transport pathway of groundwater to the Pawtuxet River. Where feasible, the selected in situ treatment will also attempt to address upland source and plume areas through a combination of technologies including excavation as part of the soil remedy and chemical oxidation.

Summary of Pre-Design Investigation and Bench Scale Test Activities

Several tasks were implemented after completion of the CMS Work Plan (AECOM, 2014) to further identify and select an appropriate in situ remedy and strategy for addressing FPA groundwater. First, PDI soil borings were advanced during September 2014, and second, geologic materials were collected for a bench-scale test to evaluate aerobic versus anaerobic biodegradation. Both efforts were completed in collaboration with and approval by EPA and the bench-scale test was discussed as a step for identifying an appropriate remedial technology for groundwater in the ~~the~~ CMS Work Plan (AECOM, 2014). During the PDI effort, soil and groundwater were sampled from four discrete intervals between the area where elevated VOCs were identified during PCB sampling by field screening with a PID in soil (E280, E300 grid points) and the downgradient groundwater plume (see **Figures 10A-J, 11A-E, and 16** for sampling locations). The purpose of these four locations was to investigate potential impacts to transition/vadose zone soils where the shallow VOC impacts upgradient may have entered the shallow/intermediate aquifer. **Figures 10A-J, 11A-E, and 16** provide plume maps that incorporate these data, as updated from those presented in the revised SRI (AECOM, 2014). The PDI data are provided in **Appendix F**. Descriptions of the sample depth intervals are provided in Section 2.5.1.

In addition to PDI activities, a groundwater remediation bench-scale test was performed to compare two candidate in situ remedial alternatives for VOC-impacted groundwater: aerobic and anaerobic enhanced biodegradation. The resulting report is provided in **Appendix F.** Soil and groundwater were collected from areas where groundwater impacts have historically been found to be significant (e.g., MP-3IS) to provide the subcontracted laboratory with the materials needed to conduct the proposed bench-scale tests. Of the evaluated treatments, the aerobic microcosms showed the most rapid decrease in COC concentrations. Corresponding plots of chlorinated compound concentration trends are presented in **Appendix F**. The rapid rates of aromatic COC degradation are consistent with the literature, however the degradation rates for chlorinated ethenes (PCE, TCE, DCE, VC) are potentially a laboratory artifact of the low starting concentrations near the method detection limit, and may not be indicative of any true transformation that may have occurred in the lab, or that might occur in the field.

During the development of the CMS Work Plan (AECOM, 2014), in situ chemical reduction (ISCR) and enhanced microbial reduction was retained as an alternative. However, it was subsequently screened out based on the outcome of the bench scale test that was performed after its publication (see **Appendix F**). While this technology did reduce some concentrations of Site COCs, the results indicated that ISCR and enhanced microbial reduction is not nearly as effective as aerobic biodegradation and had slower kinetics for treatment. Therefore, it is not considered an appropriate technology for FPA groundwater. Results of the bench scale test are included in **Appendix F**.

The following in situ treatment technologies were retained during the screening process for impacted groundwater.

In Situ Chemical Oxidation

In situ chemical oxidation (ISCO) remediates contaminants by incorporating them into oxidation reactions. Chemical oxidants are injected/sparged into the aquifer, which chemically oxidize the COCs in the source and plume. Bench scale tests and a pilot study may be warranted to optimize injection/sparge locations, rates, and volumes of ISCO compounds.

In Situ Aerobic Biodegradation

Natural aerobic microbial processes are enhanced through the introduction of oxygen or introduction of microbial populations (bioaugmentation) via injection wells to reduce concentrations of VOCs by aerobic biodegradation processes.

A bench scale test was performed from September 2014 to July 2015. The objective of the bench scale test was to compare the effectiveness of aerobic versus anaerobic biodegradation/chemical reduction of Site COCs. This technology had favorable results for reducing concentrations of Site COCs, identifying aerobic biodegradation as an effective means of treatment at the Site. Results of the bench scale test are included in **Appendix F.**

4.2.2.5 Hydraulic Control System (Groundwater Pump & Treat System)

From 1996 to 2010 Ciba operated a groundwater extraction and treatment system to hydraulically control, both horizontally and vertically, impacted groundwater and prevent off site migration of former Production Area-related impacted groundwater. Extracted water was treated on the property and discharged to the municipal treatment works. This alternative consists of repairing and restarting the existing system.

4.3 OWLA

As discussed in Sections 2.5, 3.1.3 and 3.3.2, while this area was not considered an AOC during the RFI, sampling conducted by BASF from 2012 to 2014 determined that there are sporadic residual soil impacts of PAH and SVOC that are indicative of general industrial use and development and that are in excess of the I/C DEC. As presented in Section 3.3.2, to meet the requirements of the Remedial Regulations the preferred remedy for these impacts is to remove and/or cap the impacted soils and implement an ELUR to preclude future residential use.

4.4 Production Area Pawtuxet River Sediments

Several technologies presented in the Stabilization Report (Woodward-Clyde, 1996) have already been constructed in the Production Area. The technologies that were identified to be protective of sediment and river quality include sediment excavation, disposal, capping, and extraction wells (hydraulic control system) for hydraulic control of on-site groundwater from migrating into the river. Sediment excavation, disposal, and capping was completed during a Sediment IRM in 1996 as well as an additional Sediment IRM in 2012. The groundwater extraction and treatment system operated from 1996 to 2010 when long-term monitoring data showed aquifer restoration was complete except for a recalcitrant area. The recalcitrant area was the subject of extensive remedial investigation (AECOM, 2012), and it is a subject of this CMS. Because the IRM is functioning as intended, this CMS considers only periodic sediment sand cap monitoring to confirm its integrity.

4.5 FWWTA Technologies

The FWWTA was used as a waste water treatment facility for process water generated from the Production Area. In 2004, Ciba sold the property and its current use is a landscaping operation. The property is currently zoned for commercial use.

FWWTA soil and groundwater were characterized in the RFI (Ciba, 1995) and the impacts were found to be within the acceptable USEPA target risk range for unrestricted future use (see Section 2.6). While there are no compounds that exceed the RIDEM's GB groundwater criteria, there were two samples collected in 1995 that detected the pesticide gamma-chlordane in excess of the RIDEM I/C DEC. Specifically, chlordane was detected at an estimated value of 19 ppm and 4.6 ppm in two shallow soil locations which exceeds the RIDEM I/C DEC criteria of 4.4 ppm. Though exceeding criteria, these concentrations are representative of less than the mean concentration range of residues (22 ppm - 2,540 ppm) that are around home foundations that were treated with chlordane as a pesticide (http://www.epa.gov/ttn/atw/hlthef/chlordan.html), and it is thus considered not site-related.

Based on the discussion above (here and Sections 2.6, 3.1.5 and 3.3.5), the CMS report will evaluate a No Further Action alternative for the FWWTA. Institutional controls in the form of an ELUR were initially carried forth, but the property is no longer under the control of BASF, and therefore it is not feasible to impose future use restrictions as the owner must comply. Initial screening results for the WWTA are included in **Table 8**. No Action is further described in the following section.

4.5.1 No Action

The no action technology serves as a baseline against which other corrective measure technologies can be compared. Under this alternative, no remedial action would be conducted. The contaminants are left in place without implementing any containment, removal, treatment, or other mitigating actions. In addition, the no action alternative would not include the imposition of additional institutional or engineered controls to prevent access to surface or subsurface soils. The 200 ft Riverbank Wetland boundary is established and prevents development and soil management without RIDEM approval. Finally, no ongoing monitoring is included with this alternative.

4.5.2 ELUR

Institutional controls are means of enforcing a restriction on the FWWTA that limits exposure to potentially impacted soils. The FWWTA is zoned for commercial use and currently is used as a landscaping operation. While this alternative was initially retained, the Site was sold in 2004, and BASF no longer controls future land use, therefore implementing an ELUR is not feasible as the current landowner must comply.

5.0 Development and Detailed Analysis of Corrective Measure Alternatives

This section summarizes the evaluation of retained corrective measure alternatives according to RCRA-designated performance standards. Each alternative was evaluated based on the ability to achieve three primary performance standards and six secondary balancing factors. These are the generic standards by which corrective measures are evaluated, and they apply to all media. At the conclusion of the detailed analysis of alternatives, selected corrective measure alternatives are identified.

5.1 Detailed Evaluation Criteria

Corrective measure alternatives selected for detailed analysis were evaluated according to the following performance standards:

- Primary Performance Standards, including:
  - Overall protection of human health and the environment
  - Attain media cleanup standards
  - Control the sources of releases
- Balancing factors (used to further evaluate alternatives meeting all three primary performance standards)
  - Long-term reliability and effectiveness
  - Reduction in the toxicity, mobility, or volume of wastes
  - Short-term effectiveness
  - Implementability and environmental footprint
  - Cost
  - Federal, State and community acceptance

Each of these evaluation factors is discussed briefly below.

5.1.1 Overall Protection of Human Health and the Environment

Corrective measures must be protective of human health and the environment. Alternatives may include those remedies that are needed to be protective of, but not directly related to, media cleanup, source area control, or management of contaminants. Each alternative was assessed to determine whether it can (1) adequately protect human health and the environment, in both short- and long-term time frames, from unacceptable risks posed by hazardous substances, pollutants, or contaminants and (2) eliminate, reduce, or control exposures to established remediation criteria.

5.1.2 Attain Media Cleanup Standards

Corrective measures were evaluated against the effectiveness of attaining media-specific corrective action objectives, which were derived from existing state and federal regulations, background levels, or alternative risk-based target cleanup levels. The media cleanup goals for an alternative often play a large role in determining the technical approaches of the alternative. In some cases, certain technical aspects of the alternative, such as the practical capabilities of technologies, may influence the media cleanup goals to be established. Each alternative was assessed to determine whether it would attain the treatment goals and protection standards established for the site media.

5.1.3 Control the Sources of Releases

A critical objective of any alternative is to reduce further environmental degradation by controlling or eliminating further releases that may pose a threat to human health and the environment. Unless source control measures are undertaken, efforts to clean up releases may be ineffective or, at best, will essentially involve a perpetual cleanup. Therefore, an effective source area control program is essential to ensure the long-term effectiveness and protectiveness of the corrective measure.

5.1.4 Long-Term Reliability and Effectiveness

Demonstrated and expected reliability is a way of assessing the risk and effect of remedy failure. Considerations include whether the technology or a combination of technologies have been used effectively under analogous site conditions, whether failure of any one technology in the alternative would have an immediate impact on receptors, and whether the alternative would have the flexibility to deal with uncontrollable changes at the site (e.g., heavy rain storms, tornadoes, etc.). Most corrective measures technologies, with the exception of removal or destruction, deteriorate with time. Often, deterioration can be slowed through proper system operation and maintenance (O&M), but the technology eventually may require replacement.

Each corrective measures alternative was evaluated in terms of the projected useful life of the overall alternative and its component technologies. Useful life is defined as the length of time the level of effectiveness can be maintained. In addition, each alternative was assessed for the long-term effectiveness and performance it affords, along with the degree of certainty that the alternative will prove successful.

5.1.5 Reduction of Toxicity, Mobility, or Volume of Wastes

As a general goal, alternatives are preferred that employ technologies that are capable of eliminating waste or substantially reducing the inherent potential for on-site waste to cause future environmental releases or other risks to human health and the environment. There may be some situations where achieving substantial reductions in toxicity, mobility, or volume may not be practical or even desirable. Estimates of how much the corrective measures action will reduce the waste toxicity, volume, and/or mobility are beneficial in applying this factor. The degree to which each alternative employs recycling or treatment that reduces toxicity, mobility, or volume was assessed, including how treatment is used to address the principle threat posed by impacted soil and groundwater.

5.1.6 Short-Term Effectiveness

Short-term effectiveness, or impact, is relevant when corrective measures will be conducted in densely populated areas or where waste characteristics are such that risks to workers or to the environment are high and special protective measures are needed. Possible factors to consider include fire, explosion, exposure to hazardous substances, and potential threats associated with treatment, excavation, transportation, and re-disposal or containment of waste material. The short-term impact of each alternative was assessed during the evaluation.

5.1.7 Implementability and Environmental Footprint

Implementability is often a determining variable in shaping alternatives. Some technologies will require state or local approvals before construction, which may increase the time necessary to implement the alternative. In some cases, state or local restrictions or concerns may necessitate eliminating or deferring certain technologies or remedial approaches from consideration in alternative selection. The ease or difficulty of implementing each alternative was assessed by considering the following type of factors:

- Site conditions, land use, and current operations;
- The administrative activities needed to implement the corrective measures alternative (e.g., permits, rights of way, off-site or active work zone approvals) and the length of time these activities will take;
- The constructability/time for implementation and the time required for beneficial results;
- The availability of adequate off-site treatment, storage capacity, disposal services, needed technical services and materials;
- The availability of prospective technologies for each corrective measures alternative; and
- The estimated environmental footprint resulting from implementing the alternative (e.g., air emissions, energy use, waste generation, etc.).

5.1.8 Cost

The relative cost of an alternative is an appropriate consideration, especially in those situations where several different technical alternatives for remediation will offer equivalent protection of human health and the environment but may vary widely in cost. Cost estimates include costs for site preparation, construction materials, labor, sampling/analysis, waste management, disposal, permitting, health and safety measures, training, O&M and system decommissioning/site restoration. These components, as well as other applicable costs, were used to build a cost estimate for each alternative undergoing detailed evaluation. Cost estimates were obtained from representative project experience and subcontractors for the remediation alternatives evaluated. Contingencies were also included for each remedy. Present worth costs (capital plus O&M) were estimated to +50/-30 percent range. Cost estimates for evaluated alternatives are included in **Appendix C** for soil alternatives and **Appendix E** for groundwater remedial alternatives.

5.1.9 Federal, State and Community Acceptance

Evaluation of selected corrective measures must consider federal (USEPA), state (RIDEM), and community acceptance. As BASF has entered into a consent order with USEPA, this performance standard will evaluate each alternative with respect to implementation in accordance with USEPA consent order requirements and any other requirements or input received from USEPA pertaining to remediation at the Site.

Each alternative will also be evaluated with respect to potential impacts to the surrounding community (residences, local businesses, etc.). A preferred alternative will be selected. A Statement of Basis that describes the remedy will be issued by EPA, and a public comment period will commence, during which time, questions, comments or concerns may be submitted for response.

5.2 Corrective Measure Detailed Analysis Results

Given the discussion in Section 4, there are three remedial measures where alternative evaluation is required: FPA Soil, FPA groundwater and FWWTP soil. At the OWLA, the observed urban impacts will be addressed through removal and/or capping and the use of an ELUR to guide future use of this area. For the Pawtuxet River sediments, because the IRM is functioning as intended, a monitoring plan is the presumptive remedy.

5.2.1 FPA Soil

Details and descriptions of each of the six retained technologies are included in **Table 9**. The detailed analysis of the retained soil corrective measure alternatives is provided in **Table 10**. Each alternative was ranked on a scale of 1 to 6 (1 being the best) in **Table 10** with respect to the nine performance standards described above. The results of the analysis indicate that remediation to the strictest remedial standard is the most favorable outcome; however, based on cost, expected future use and implementability (recall that extensive subsurface concrete foundation structures remain in place which will encumber excavation activity), the high occupancy re-use option consisting of removal of soils with greater than 10 ppm of PCBs was chosen as the most appropriate remedy for the Site. A detailed description of the selected corrective measures and evaluation is provided in **Section 6.1**.

5.2.2 FPA Groundwater

Details and descriptions of each of the seven retained technologies are included in **Table 11**. The detailed analysis of the retained groundwater corrective measure alternatives is provided in **Table 12**. Each alternative was ranked on a scale of 1 to 7 (1 being the best) with respect to the nine performance standards described above. When assessing the best remedial alternative, one must consider the key physical attributes of the Site and the nature and extent of impact, summarized below:

1. The recalcitrant groundwater impact zone that is the focus of the remedial action considered here is associated with contaminant releases that occurred more than 40 years ago. In addition, for 12 years a groundwater capture system was operated as an IRM to address this impact by controlling groundwater discharge to river sediments and surface water (the identified receptor pathway). A second remedial system was installed and operated as an IRM to remove mass that was released from a toluene pipeline break by using soil vapor extraction (SVE) in the FPA. While some residual source is still present in upland portions of the FPA, in downgradient areas these conditions combine to result in the delineated recalcitrant mass occurring primarily as adsorbed and dissolved phase adjacent to and within the low conductivity aquifer material (silt). This mass is slowly back diffusing into the more permeable units to create the groundwater plume that is observed to be approaching the river today. Some mass that was identified in shallow areas in 2014 will be removed and disposed off-site. A remedial action that attempts to address this entrained mass through amendment emplacement will need to be applied on a fine spatial scale owing to the low conductivity material characterizing the aquifer.

2. The impact area is below and around former building foundations and footings and pilings that remain in place. These extensive concrete structures will significantly limit the ability to apply necessary amendments at the appropriate scale in terms of required spatial distribution and volume acceptance for a plume-wide approach.

3. The proposed soil remedy includes the installation of a high occupancy cap with an ELUR requiring cap maintenance and limited Site use, and the groundwater resource is classified as GB, not for potable use. Thus, it is evident that the only complete current or future exposure pathway for this groundwater impact is groundwater discharge to river sediments and surface water. The 1995 IRM relied on groundwater containment at the bulkhead to eliminate this pathway, and a performance monitoring plan was implemented to verify that the pathway was incomplete based on MPS defined for the 5 Site VOCs.

4. One must consider the suite of compounds that a biologically-based remedial action must address. These include the five VOC COCs commonly used in the production process, identified in 1995 and assigned MPS, namely: 1,2-dichlorobenzene, chlorobenzene, 2-chlorotoluene, toluene, and total xylenes. In addition to the COCs listed above, there is a sub-area where other VOCs are uniquely identified as exceeding the RIDEM GB criteria. These include: tetrachloroethene, vinyl chloride and benzene. These compounds are not detected in on-Site soil at elevated concentrations and not likely source material based on past operational activity. Nevertheless, these compounds are generally co-located with one or more site-related COCs in excess of an MPS, and, will thus be addressed through remedial action.

   Given these target compounds, the issues for a biologically-based alternative are (1) choice of aerobic, anaerobic, or both, and (2) amendment choice and delivery method. During the CMS, effort was put into a study to determine if aerobic or anaerobic mechanisms are optimal in this system and aerobic was determined to be the most effective for the suite of compounds (**Appendix F**). However, in the field there are the following challenges:

   a. Amendment delivery – as stated above most of the residual source mass is entrained in low conductivity material, and the presence of significant subsurface structures will limit amendment delivery within the treatment volume.
   b. The current conditions are anaerobic which puts attritional onus on oxygen delivery to support an aerobic process.
   c. While aerobic and anaerobic modes of degradation are apparent, there is a likelihood that the degradation of chlorinated benzenes by either mechanism could be incomplete.

   There is no such ambiguity with the use of ISCO in general and ozone sparging in particular. The benefits of ozone sparging include the fact that it is among the most powerful oxidants with a very high negative Gibb's Free Energy that can degrade all the Site COCs, and if applied continuously, one can avoid the pitfalls inherent in the use of liquids and common rebound effects.. Also an ozone sparge curtain has advantages not the least of which is that dissolved-phase gas can permeate low conductivity aquifer soils more effectively than can liquids. A byproduct of an ozone approach is oxygen, and it will act to stimulate aerobic biodegradation.

5. Source material discovered as part of the PCB characterization and follow-up PDI (see Section 2.5.1), can be addressed in part during the PCB-impacted soil removal (over-dig), and in part by applying an oxidant in the excavation hole near the water table to address shallow residual source material before regrading occurs. The proposed oxidant is activated sodium persulfate and is well known to completely degrade the five MPS compounds.

6. Natural attenuation of the Site VOC is apparent from the data collected during the SRI (AECOM, 2014). Across the sampled wells, reducing conditions and degradation products (an indication of biotic degradation/activity) are apparent, as evidenced by the low dissolved oxygen and nitrate concentrations, and the presence of methane. Bacterial counts in the groundwater are high relative to unimpacted aquifers. This would indicate that the presence of chlorobenzenes and other aromatics has stimulated the microbial population in the subsurface.

Thus, given the concepts that the purpose for the remedial action for groundwater is to protect the river sediment and water quality, that the contaminant dissolution processes are slow, that residual source material associate with SWMU11 will be addressed as part of the PCB remedy (excavation and ISCO), and that natural anaerobic degradation processes persist in the upland aquifer, the installation of an ozone sparge curtain reactive barrier between the impact zone and the river will effectively protect the river while providing support to the naturally occurring degradation processes (provide an oxygen source to support aerobic biodegradation downgradient of the sparge curtain).

This alternative is thus promulgated by this revised conceptual site model where:

1. Residual source mass was discovered in September 2014 in areas adjacent to where the former SVE system (SWMU 11) operated. This material will be removed as part of the broader groundwater remedy;
2. The remedy relies on existing natural degradation processes to address residual dissolved-phase mass in upland aquifer materials;
3. It replaces the former IRM hydraulic containment system with an ozone sparge curtain reactive barrier placed between the upland and the river to meet the objective to treat the shallow and deep portions of the aquifer and protect the river receptor; and
4. It employs the ELUR that is necessary to implement the soil remedy to eliminate direct contact considerations and provide for long-term operation, maintenance and monitoring access.

The results of the analysis indicate that ISCO and in situ aerobic biodegradation ranked best among the retained alternatives. A detailed description of the selected corrective measures and evaluation is provided in **Section 6.2**.

5.2.3 FWWTA Soil

No further action is warranted and carried forth as the remedy for the FWWTA based on development constraints requiring RIDEM approval for future development, the commercial zoning, and the conclusion of no significant risks based on a conservative unrestricted use scenario. An ELUR was carried forth in the CMS Workplan (AECOM 2014), however, the property was sold in 2004 and thus future uses can no longer be dictated by BASF. A detailed description of the selected corrective measure and evaluation is provided in **Section 6.3**.

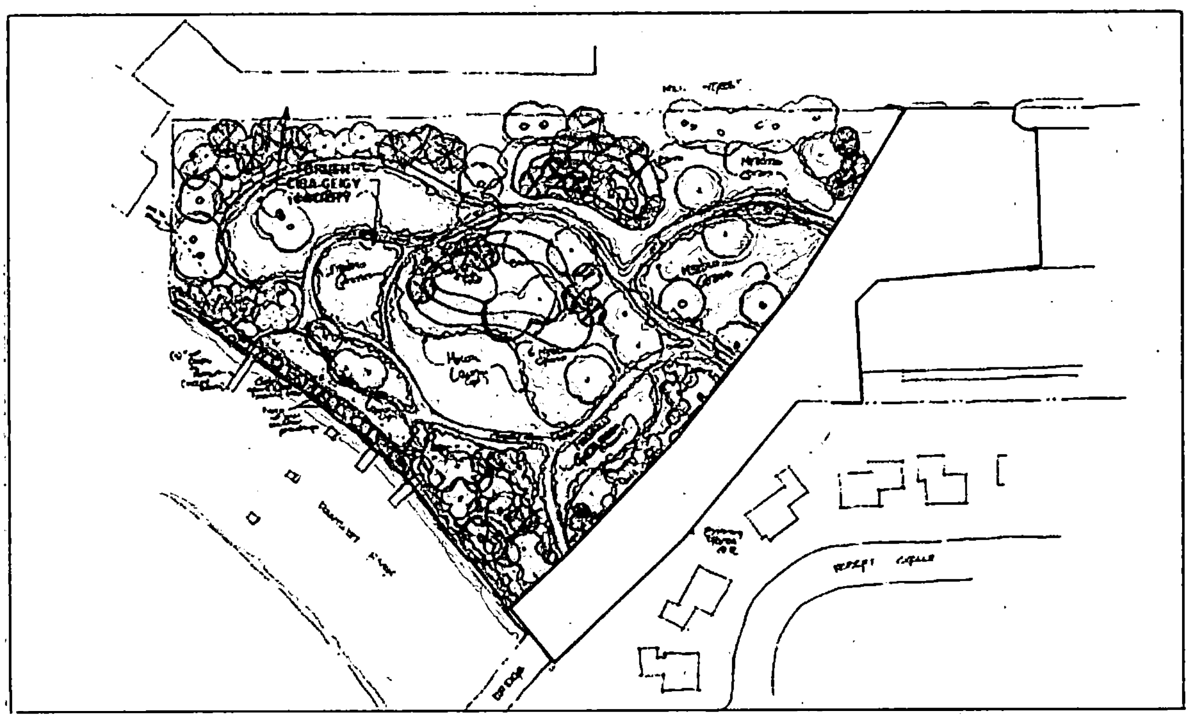
6.0 Evaluation of a Selected Corrective Measure Alternative

6.1 FPA Soil Selected Remedy

The selected corrective measure to remediate soils is as follows:

1. Excavation and disposal of soils -impacted with PCBs greater than 10 ppm at an appropriate, regulated disposal facility.
2. Limited on-site reuse/consolidation of soils with PCB content greater than 1 ppm.
3. Installation of a regulatory-conforming high-occupancy cover over soils with PCB content greater than 1 ppm and SVOC content greater than the RIDEM IC-DEC. The cover will be constructed and contoured to support a diverse native upland habitat.
4. The septic tank located east of Building 14 will be closed and/or removed during implementation of this remedy.
5. The imposition of an ELUR on the FPA, to be approved by the RIDEM, requiring, at a minimum, open space reuse only and long-term cap maintenance and monitoring.

Figure 18A and Figure 18B show two conceptual scenarios of the proposed excavation and extent of the high-occupancy cover, and Inset Figure 1 provides a conceptual regrading and native habitat enhancement plan associated with the FPA high occupancy cover remedy.



Inset Figure 1 – Conceptual regrading and native habitat enhancement plan associated with the FPA high-occupancy cover remedy and open space/parkland reuse.

Complete removal of the impacted soils is not feasible because of the fact that they are in large part located within and around former building foundations, footings, and pilings. These extensive concrete structures will limit the ability to fully remediate the area to avoid the need for a cap. However, while a cap is needed, this remedial action will allow for a high-occupancy reuse which will allow the entire FPA to be repurposed as open space/parkland), thus providing socio-economic value. ~~Therefore, under this corrective action, future Site use will be limited to industrial/commercial and open space use, but further restrictions (i.e. low-occupancy use) will not be stipulated as a condition of the remedial option. Under this remedy, soils greater than 10 ppm are excavated and shipped for off site disposal at appropriate disposal facilities and a high-occupancy use cap meeting RIDEM stipulations for limiting direct exposure will be placed over areas shown to have PCB impacts greater than 1 ppm. Targeted excavation and/or capping will be utilized for areas of SVOC impacts present in limited areas that are greater than the I/C DEC. The septic tank located east of Building 14 will be closed and/or removed during implementation of this remedy.~~

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Costs and assumptions associated with implementation of the proposed remedy are presented in **Appendix C**. This represents one such scenario for this chosen option. PDI and/or post-excavation sampling may change estimated volumes and areas proposed for excavation and on-site reuse/consolidation, but the intended future use scenario will be retained as described above. The cost of the actual remedy could be different than that presented in Appendix C and will be based on the final design.

6.1.1 Remedial Approach

Excavation of PCB-impacted soils will occur in multiple phases, which may be sequential or overlap during implementation. All work will be performed following both EPA (TSCA) and RIDEM regulations. The phases are outlined below:

- **Phase I** - Excavation, verification sampling and offsite disposal of all TSCA-classified soil (i.e., soil impacted with greater than 50 ppm of PCBs). See Figure 18A and Figure 18B for two scenarios showing the target areas. As the targeted volumes are removed, a TSCA-conforming verification sampling plan will be implemented to ensure that the 50 ppm threshold has been achieved. Before excavation, disposal will be coordinated with transport contractors and disposal facilities equipped to accept the estimated volume of TSCA waste [currently 1,170 cubic yards (CY)]. ~~A sampling plan to confirm soils with PCBs greater than 50 ppm have been removed will be included in a future design~~.
- **Phase II** - Excavation, verification sampling and offsite disposal of all soil impacted with greater than 10 ppm of PCBs (i.e., the EPA requirement to allow for a high-occupancy reuse scenario). See Figure 18A and Figure 18B for the conceptual target areas. As the targeted volumes are removed, a TSCA-conforming verification sampling plan will be implemented to ensure that the 10 ppm threshold has been achieved. Before excavation, disposal will be coordinated with transport contractors and disposal facilities equipped to accept the estimated volume of non-hazardous waste containing PCBs less than 50 ppm [currently 5,100 CY].~~Disposal will be coordinated with transport contractors and disposal facilities equipped to accept up to 5,100 CY of non-hazardous waste containing PCBs less than 50 ppm. A sampling plan to confirm soils with PCBs greater than 10 ppm have been removed will be included in a future design.~~
- **Phase III** – Cover (cap) remaining soils with concentrations greater than1 ppm with two feet of clean soil to meet RIDEM direct exposure requirements. Where soils are consolidated, employ a verification sampling plan to ensure uncapped areas conform to the threshold. At

this point in the project, excavated materials will contain less than 10 ppm PCBs, which are suitable for on-site reuse under this corrective action. On-site reuse will consist of backfilling open excavations within the area to be capped to consolidate the material. Excavation areas not to be capped will not be backfilled, but will be graded to eliminate sharp changes in elevation. Within the flood hazard area, the grading plan will conform to the no-net-increase-in-fill requirement. The final cap will be constructed with clean soils containing less than 1 ppm of PCBs. Approximately 1,520 CY of clean material will be required to construct a cap two feet thick, which covers an area of approximately 39,000 SF, over the area containing the consolidated soils. The final location and quantities of the cap will be established in the Remedial Design process with the goal that all soils containing PCBs >1 ppm remaining on-Site will be capped with 2 ft of clean material. The cap will be completed and vegetated to support a diverse upland habitat. ~~Soil containing PCBs between 1 and 10 ppm outside of the area to be capped will be excavated such that a 2 ft soil cap is present across the entire site. Excavation areas will be required to maintain current grades within the 100 year flood plain boundary. Consideration was also made to keep the cap relatively flat near the property boundaries. Excavated materials will contain less than 10 ppm PCBs, which are suitable for on-site reuse under this corrective action. On-site reuse will consist of backfilling open excavations within the area to be capped to consolidate the material (3,800 CY). Excavation areas not to be capped will not be backfilled, but will be graded to eliminate sharp changes in elevation.~~

- **Phase IV –** Impose an Environmental Land Use Restriction (ELUR) on the entire FPA, to be approved by the RIDEM, requiring, at a minimum, open space reuse only and long-term cap maintenance and monitoring.

ADD REQUIREMENTS TO DO RIVER SEDIMENT SAMPLING

~~Construction of a cap with clean materials containing less than 1 ppm of PCBs. Approximately 1,520 CY of clean material will be required to construct a cap two feet thick, which covers an area of approximately 39,000 SF, over the area containing the consolidated soils.~~

~~The final location and quantities of the cap will be established in the Remedial Design process with the goal that all soils containing PCB >1 ppm remaining on-Site will be capped with 2 ft of clean material.~~

As discussed in Section 3.1.1, caps used as remedial measures under TSCA 40 CFR 761.61(a)(7) are required to meet permeability, sieve, liquid limit and plasticity requirements. Variation from these requirements will require approval from EPA. In areas where PCBs will remain on-site at concentrations between 1 and 10 ppm, the RIDEM remediation regulations require that contact with such soil be eliminated by rendering it inaccessible beneath 2 ft of clean soil with no permeability requirement as 10 ppm meets the RIDEM GB leachability requirement. A clean soil cap of 2 ft also meets the minimum thickness requirements (10 inches) required by TSCA 40 CFR 761.61(a)(7). This RIDEM-based measure to render the soil inaccessible is an effective means of compliance with the DEC when the soil cap is maintained through implementation of an ELUR that details the configuration of the inaccessible soil area and requires that the cover be maintained. Therefore, a RIDEM cap is considered a feasible alternative to that required under TSCA 40 CFR 761.61(a)(7).

Cap materials will consist of at least 2 feet of clean materials (e.g. sand and top soil) overlying indicator materials (e.g. geotextile liner and orange fencing material) to delineate clean versus impacted soils as a warning of inadvertent disturbing of the cap.

6.1.2 Comparison of Selected Alternative to Performance Standards

This section provides an evaluation of the selected corrective measure with respect to RCRA performance standards as described in **Section 5.0**. The selected corrective measure consists of excavating soils impacted with PCBs to a 10 ppm threshold, capping soils with PCB concentrations greater than 1 ppm, but less than 10 ppm. Vadose zone soil containing elevated levels of VOCs, as well as soil near the on-Site buildings exceeding the RI DEM I/C DEC will also be removed (see discussion in Section 5.2.2). This corrective action is consistent with anticipated future use.

Protection of Human Health and the Environment

The selected alternative is protective of human health and the environment. Excavation/disposal/capping of soils to be consistent with RI DEM I/C DEC is considered appropriate for anticipated future uses as I/C property.

Attain Media Clean-up Standards

The selected alternative will achieve site-specific CAOs for soil. Excavation and disposal, with capping, is one of the most conservative and successful means to obtain clean-up goals.

Control Sources of Releases

Elevated PCB impacts will be excavated and appropriately disposed, effectively eliminating the potential for residual PCB impacts to act as a continuing source.

Long-term Effectiveness

Excavation and disposal is effective long term, and caps will be monitored to ensure there is no erosion or other means of destruction is present.

Reduction of Toxicity, Mobility and Volume of Wastes

The selected alternative will reduce the toxicity, mobility and volume of wastes.

Short-term Effectiveness

The excavation/capping plan can be implemented with acceptance of the remedial alternative. Once the remedy has been accepted, design and permitting, and procurement of an excavation subcontractor can be implemented within 6-12 months. The short-term impacts on the community will be limited by minimizing the amount of soil transported for off-site disposal.

Implementability and Environmental Footprint

Operations have ceased at the Site, thus, there are currently no existing conditions at the Site that would prevent or make difficult any of the above activities. Therefore, this alternative is considered implementable.

The environmental footprint associated with implementing this remedy is considered as having less impact than the option for unrestricted use based on reduced volumes of soil requiring handling, disposal, and subsequent backfill.

Working in and around building foundations will limit the ability to remediate to a goal of 1 ppm, thus requiring at a minimum the imposition of an ELUR and likely the use of a cap in places. These facts make the 10 ppm cleanup goal more implementable.

Cost

The cost of this remedial strategy was more expensive than a low-occupancy scenario (soils greater than 50 ppm were remediated, all others capped), but less expensive than the strictest remedial standard option (remove all >1 ppm).. The cost-benefit relationship balances the total remedial costs with likely future use, and the ability of the performing party to transfer the property in the future.

Federal, State and Community Acceptance

In general, excavating PCB-impacted soils and capping residual impacts to a 10 ppm threshold would be accepted by various federal, state, and local stake holders. The corrective measure adequately addresses risk to human health and the environment for likely future use scenarios without limiting occupancy for the IC use category.

Permits from the City of Cranston Planning and Zoning and RI DEM Wetlands department would be needed to excavate within the 100-yr flood plain and the wetland buffer zone within the Pawtuxet River areas.

This alternative will incorporate comments following the public notice comment period.

6.2 FPA Groundwater Selected Remedy

Groundwater will be addressed through a three step plan. First, residual VOC source material located in the upland near SWMU11 will be in part excavated from the vadose zone as part of the PCB remedy and disposed of offsite and in part destroyed in-situ with a chemical oxidant (base or peroxide activated sodium persulfate) by physically mixing the oxidant into the vadose and saturated zones before re-grading the area to support the soil cover. Second, for the groundwater plume that has migrated to the vicinity of the river bulkhead, an in-situ reactive barrier will be installed parallel to the river bulkhead and normal to the groundwater flow direction to destroy VOC mass in-situ before it migrates off-site and discharges to the Pawtuxet River. The proposed oxidant is ozone, and it will be applied to the aquifer in a continuous fashion using a line of wells that overlap in their volume of influence (a sparge application). The remedy will be run on the order of years until such time as upgradient and downgradient monitoring show that the media protection standards have been met. The ozone will destroy all contamination in which it comes in contact, and it will also contribute oxygen to the groundwater to support aerobic biological degradation. The remedy design including the treatment volume, number and orientation of injection wells, and monitoring requirements will be determined from a pilot testing program. Third, for dissolved upland VOC mass, monitored natural attenuation (MNA) will be used to show mass attenuation over time. These remedial measures in concert are appropriate given site-specific conditions including extensive in place building foundations which limits access to aquifer materials and low conductivity heterogeneous aquifer material coupled with the age of the impacts (greater than 40 years) which limits the mobility of the dissolved-phase mass. Finally, this remedy is consistent with that proposed for the upland soils and the imposition of an ELUR that will limit future land use to open-space and require long-term operation and maintenance.

MNA analysis parameters

~~The selected corrective measure for FPA groundwater consists of a three prong approach to address residual VOC source material, dissolved VOC phase mid-plume impacts, and the transport pathway from upland FPA aquifer impacts to the Pawtuxet River. Shallow soils with residual impacts in upland areas downgradient of SWMU11 will be excavated as part of the PCB remedy and the base of the~~

~~excavation will be treated with an oxidant to remediate potential on-going sources. MNA will be used to treat mid-plume areas. To break the transport pathway and to be protective of the Pawtuxet River, a reactive barrier consisting of focused in situ remediation (using ISCO and aerobic biodegradation) of shallow and deep portions of the southern Production Area aquifer will be implemented where groundwater is impacted with concentrations that exceed the MPS criteria and GB groundwater objectives at the upgradient side of the bulkhead to the Pawtuxet River. A treatment area will be established adjacent to the river and in situ remediation would break the transport pathway by treating the COCs dissolved in groundwater and sorbed to soil. Prior to full-scale implementation, pilot testing of the ISCO technology will be performed. Based on the results of the testing, the ISCO remedial technology or combination of remedial technologies will be implemented and final treatment areas would be established.~~ The conceptual remedial area is illustrated in **Figure 16** and constitutes a remedial measure that is protective of the river, removes on-going sources, and monitors for natural attenuation between the source and treatment barrier located adjacent to the river.

Details on costs and assumptions for implementation for the in situ remediation alternatives are included in **Appendix E**. Amendment quantities and injection rates/durations were estimated. The potential technologies to be used are described below.

6.2.1 In-Situ Chemical Oxidation – Source Zone

ISCO is the selected remedial alternative to treat COCs in the shallow groundwater interval of the residual source zone in upland portions of the FPA associated with SWMU11 (see **Figure 16** for location). –The target COCs for treatment are 1,2-dichlorobenzene, chlorobenzene, 2-chlorotoluene, toluene, and xylenes. Base or peroxide activated sodium persulfate are proposed oxidants. Persulfate has been effective at oxidizing the targeted COCs (e.g. Sedlak and Andren, 1991, Huang, *et al.*, 2005, ITRC, 2005, and Luo, 2014).

6.2.1.1 Description of Technology

ISCO involves the injection of an oxidizing substrate to the subsurface with the objective of promoting oxidation of target compounds to benign end products. Activated sodium persulfate is proposed for the remedial approach. Sodium persulfate is a strong chemical oxidant that can persist for weeks to months. This attribute will allow some portion of the persulfate to be transported under induced and natural gradients prior to fully reacting, allowing the oxidant to get better distribution in the subsurface and treat more contaminant mass downgradient from the residual source area. For remediation applications, sodium persulfate needs to be activated (catalyzed) in order to form powerful free radicals, including sulfate radicals ($\cdot SO_4^-$), which are more powerful oxidants than persulfate. Activating agents include elevated temperatures, ferrous iron (Fe(II)), elevated pH (base), and peroxide.

6.2.1.2 Remedial Approach

The remedial approach in the residual source area is to first excavate VOC-impacted soil in the vadose zone and dispose of it at an appropriate disposal facility. This excavation will occur at the same time as the remediation of the PCB-impacted soil. Based on the PDI data, the excavation is initially planned to encompass an area of 400 to 750 square feet, and it will extend to the water table. ~~,~~ Excavation will be monitored with visual cues (i.e. staining) and photo-ionization detector (PID) as screening tools, and if necessary it will be expanded in area initially based on screening and subsequently based on confirmatory sidewall sampling to compare concentrations to RIDEM GB Leachability Criteria.- ~~depending on the impacts identified in the field and results from confirmatory sampling. The excavation will be dug to the water table.~~

Once vadose zone mass has been removed, the oxidant will be placed in the excavation and mixed into the top three to four feet of the saturated soil within the shallow aquifer using an excavator bucket of specialized excavator attachment. The oxidant dosing will be based on the total oxidant demand of the soil and a factor of safety. The volume of oxidant solution (diluted with water) will be equivalent to at least approximately 3 pore volumes of the saturated thickness of soil to allow for the oxidant to disperse away from the excavation. The excavation will then be backfilled.

~~Activated persulfate has documented success in treating chlorobenzene, 1,2-dichlorobenzene, 2-chlorotoluene, benzene, toluene, xylenes, and chlorinated ethenes (e.g. PCE and TCE) (ITRC, 2005). The assumptions used for the remedial approach include using persulfate in the upland portions of the treatment area, which persists from weeks to months. The rationale for using persulfate would be that some portion of the persulfate will transported under induced and natural gradients prior to fully reacting, allowing the oxidant to get better distribution in the subsurface and treating more contaminant mass downgradient from the residual source area.~~

Approximate excavation and mixing locations and volumes were evaluated in this CMS and are included in **Appendix D**.

6.2.2 In Situ Chemical Oxidation – Pawtuxet River Barrier

ISCO is the primary remedial technology selected for a treatment barrier located adjacent to/upgradient of the Pawtuxet River. The treatment barrier will be installed into the upland aquifer along a transect parallel to the bulkhead along the Pawtuxet River destroying contaminants in situ. The purpose of the barrier is to break the transport pathway and treat impacted groundwater discharging to surface water. This approach is protective of the sensitive receptor. This remedy will employ an ozone sparge curtain to fully treat the COCs located in the southern portion of the FPA. Continuous operation of the sparge curtain will intercept Site COCs in permeable transport pathways.

6.2.2.1 Description of the Technology

This alternative involves installing an ozone sparge barrier using a series of closely spaced wells through which ozone is forced into the aquifer under pressure between the upland aquifer and the Pawtuxet River to destroy the resident COCs as they migrate.

Ozonation is a very common potable water and wastewater treatment technology. Over the past 25 years, more and more case study literature has been published that supports the concept of also using ozonation for treating complex organic pollutants, including the VOCs detected at the Site (http://www.kerfoottech.com/ and Siegrist et al., 2011).

Ozone is one of the strongest oxidants available for in-situ chemical oxidation; therefore, it should be effective at remediating the VOCs. The barrier system will remediate the COCs directly upgradient of the bulkhead in efforts to meet the remedial action objective to protect river sediments and surface water from discharging site-related contamination.

A monitoring plan will be implemented to determine the effectiveness of the barrier by providing a measure of the mass flux of contaminants across the barrier (a function of barrier thickness and continuity), where dedicated wells are installed upgradient, within and downgradient of the barrier along flow lines, and they are monitored for COCs, as well as, geochemical parameters (e.g. dissolved oxygen, specific conductivity, pH, turbidity). The barrier will be operated until such time as mass transport from the upland no longer affects water quality above the MPS or GB criteria at the downgradient monitoring point. In addition to barrier functionality, these data are used to provide design information regarding barrier dosing requirements and natural attenuation of residual dissolved mass located up-gradient of the barrier.

6.2.2.2 Remedial Approach

The treatment barrier will be designed to remediate the shallow and deep zones that exceed the applicable MPS or GB standard for those target compounds with no MPS. For the purposes of this CMS, one such conceptual approach is carried forth to demonstrate a potential treatment geometry (**Appendix D**). This is based on the high resolution hydrogeological data collected during the site investigation. The estimated area of the treatment barrier is 200 ft long by 40 ft deep [between 6 and 46 feet below ground surface (bgs)]. Typically, vertical injection wells are used and they are spaced and screened to target the ozone where required. The estimated number of ozone injection wells in the shallow zone is five (5), and in the deep zone is thirteen (13). This is based on an estimated zone of influence of 15 feet.

Performance monitoring will be used to determine the barrier's effectiveness. Overall performance will be evaluated based on concentration trends and achieving MPS or RIDEM GB groundwater criteria for the identified COCs. It is worth reiterating that a byproduct of ozone degradation is dissolved oxygen, which has been shown to stimulate bacterial populations found at the Site (Appendix F), which enhances natural attenuation.

The infrastructure required for the duration of the remedy will include the ozone source and the equipment and power needed to deliver it into the aquifer (housed in a trailer located near the application area), and a series of injection wells (with trenched piping) and performance monitoring wells.

A pilot test will be implemented to show proof of concept and establish design parameters to support the full scale application, specifically the spacing and orientation of injection wells and the need for surface area enhancement in the subsurface should low permeability aquifer materials inhibit distribution. Performance monitoring will occur in upland locations upgradient and downgradient of the piloted barrier. Performance sampling parameters will be outlined in a pilot test work plan, but they typically include sampling for contaminants, groundwater elevations, temperature, flow rates of the injected oxidant, wellhead pressure, geochemistry (e.g. dissolved oxygen, specific conductivity, pH, turbidity), total dissolved solids and/or select metals, and total organic carbon. The frequency and duration of monitoring will be established in a pilot test work plan, but the plan will consider appropriate timeframes to establish effective zone of influence and effectiveness of the oxidant to treat the COCs. Results from the pilot test will be used to develop the full-scale design of the barrier.

6.2.3 Aerobic Biodegradation – Pawtuxet River Barrier

Aerobic biodegradation is a secondary option for implementation as the selected remedial alternative to treat COCs in more permeable portions of the aquifer located near the bulkhead. The target COCs for treatment are 1,2-dichlorobenzene, chlorobenzene, 2-chlorotoluene, toluene, and xylenes. In addition, aerobic biodegradation has been shown to degrade chlorinated ethenes in the laboratory bench scale test, but should be confirmed with field data from a pilot test prior to full-scale implementation, if implemented.

6.2.3.1 Description of Technology

Aerobic biodegradation uses indigenous or introduced aerobes to biodegrade COCs. Frequently, impacted aquifers are oxygen-limited, thus implementation of this technology often involves reintroducing oxygen to the aquifer to accelerate naturally-occurring in situ bioremediation. To this end, commercially available products are available to distribute high concentrations of dissolved oxygen into the aquifer via oxygen diffusers (e.g. in situ Submerged Oxygen Curtain [iSOC]) installed into screened wells within the treatment interval. Oxygen is passively distributed to the diffusers in the wells using regulated tank pressure. Super-saturated dissolved oxygen-infused groundwater is then transported under natural gradients, which then becomes available to aerobic bacteria. Bench scale tests have shown this aerobic bioremediation to be effective for Site COCs using geologic materials collected at the Site.

6.2.3.2 Remedial Approach

A conceptual approach is described for implementation of aerobic biodegradation as a treatment barrier which includes installing wells along the length of a transect located adjacent to the Pawtuxet River in a barrier geometry. Oxygen diffusers will be installed in the wells, which will be screened from approximately 16-26 ft bgs, or deeper if warranted. The screened interval will intersect permeable portions of the aquifer that act as transport pathways from upland portions of the FPA to the Pawtuxet River. Dissolved oxygen (DO) concentrations approach 30-50 mg/l within the well. DO-saturated groundwater is then transported from the wells under natural gradients and dispersed into the aquifer stimulating the native aerobic microbial populations, which degrade COCs. Because diffusion is the main mechanism for distribution of DO-saturated groundwater, the barrier geometry differs from the ozone sparge technology described above. Where the ozone sparge must contend with application of a gas which may be bouyant and placed below the treatment interval, the oxygen diffusers may be screened across the intervals with the highest mass flux, hence a slightly different treatment geometry, but with similar outcomes.

Aerobic biodegradation has documented success in treating chlorobenzene, 1,2-dichlorobenzene, 2-chlorotoluene, benzene, toluene, xylenes, and the lower order chlorinated ethenes (e.g. TCE, VC). PCE has been shown to be degraded by co-metabolically produced enzymes from bacteria that consume other carbon sources for food in the subsurface. The assumptions used for the remedial approach include using dissolved oxygen in the vicinity of the Pawtuxet River. An approximate barrier location was evaluated in this CMS and is included in **Appendix D.**

6.2.4 Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) is a technology that relies upon the natural reduction of contaminant concentrations in groundwater resulting from the combined effect of dispersion, diffusion, volatilization, sorption, abiotic degradation, and biodegradation. MNA is incorporated as a component of the remedial approach to document restoration of the upland aquifer over time. ~~the middle portion of the plume between the treatment barrier located adjacent to the Pawtuxet River and downgradient of the source area treatment to address residual contamination associated with areas that were not subject to the in situ remediation treatment~~.

6.2.4.1 Description of Technology

MNA quantifies natural attenuation mechanisms that are active at the Site. These include: dispersion, diffusion, volatilization, adsorption, abiotic degradation and biotic degradation. Dispersion and diffusion are transport mechanisms that reduce COC mass flux across a unit area and COC concentration at monitoring locations, but not the total mass in the aquifer (i.e., a dilution phenomenon). The heterogeneous and low conductivity nature of the aquifer materials will promote dispersion and diffusive transport into fine-grain materials, where discharge will be reduced and where biotic and abiotic degradation has an opportunity to reduce the mass in place. Volatilization is a function of the contaminant's volatility (defined by its Henry's law constant) and site specific considerations, including proximity to the COC impact to the water table and the conductivity of the aquifer materials. Sorption to aquifer materials is a function of the aquifer's organic carbon content and the contaminant's affinity for that carbon (defined by its K_{OC}). Degradation of the contaminants through abiotic (chemical reactions with aquifer minerals) and/or biotic (chemical reactions with bacteria resident in the aquifer matrix) means is an attenuation mechanism, where the contaminant mass is destroyed in-situ through these natural processes.

6.2.4.2 Remedial Approach

MNA will be implemented by monitoring the spatial and temporal trends in concentration at locations along mid-plume locations and the downgradient side of the reactive barrier to verify that there is a restorative trend in general and to show that COC concentrations leaving the Site are below respective MPS and GB criteria during and after operation of the reactive barrier. Based on an evaluation of MNA parameters at the Site, MNA will complement the active ISCO/aerobic treatment.

As part of the remedial investigation, MNA parameters were collected in the vicinity of the reactive barrier-, and the following conclusions are presented:

- Across the sampled wells, reducing conditions (an indication of biotic degradation) are apparent, as evidenced by the low dissolved oxygen and non-detect nitrate concentrations, and the presence of methane. In this situation, the strongest evidence of reducing conditions is the presence of methane.
- Bacterial counts in the groundwater are high relative to unimpacted aquifers. This would indicate that the presence of chlorobenzenes and other aromatics has stimulated the microbial population in the subsurface.
- ~~Nitrate was not detected, suggesting that the current primary terminal electron acceptors are Fe(III) and sulfate.~~ After oxygen depletion, denitrification takes place. During this time, all aromatic VOCs measured (toluene, total xylenes, chlorobenzene, 1,2-dichlorobenzene, benzene, 2-chlorotoluene) were likely actively mineralized. Once oxygen and nitrate are consumed, mineralization of the COCs decreases.
- The enzymes oxygenesases (both mono- and di-) are present, and while they require oxygen to function, they are instrumental in mineralizing the benzene-related COCs.

In summary, based on the available data, an active microbial community is present at the Site. Presently, it is electron acceptor-limited and therefore unable to fully degrade the contaminants. Under the current conditions, the community is actively dechlorinating higher chlorinated aromatics. With the reintroduction of an electron acceptor (e.g. O_2), the microbial population would likely resume rapid degradation of chlorobenzene, 1,2-dichlorobenzene, benzene and lower chlorinated aromatics.

A monitoring program will be implemented to analyze trends of COCs and pertinent MNA parameters upgradient and downgradient of the reactive barrier. The performance monitoring parameters and frequency will be outlined in a Remedial Action Work Plan, but they typically include sampling for the COCs, geochemistry (e.g. dissolved oxygen, specific conductivity, pH, turbidity), total organic carbon, terminal electron acceptors (e.g. nitrate, sulfate, iron), and occasional bacterial census to evaluate whether bacterial populations at the Site continue to be present in sufficient numbers to effectively treat COCs. Performance monitoring evaluations will be conducted in concert with the ISCO barrier performance evaluations to determine whether natural attenuation is sufficient to address groundwater impacts in concert with or independently of the ISCO barrier approach. It is anticipated that over time

MNA will become the sole groundwater remedy based on the record of spatial and temporal trends in COC concentration.

It is worth noting that injected reagents will likely work cooperatively with the available microbial populations. In addition to potentially stimulating the aerobic biological pathway, generation of heat through the ISCO process should stimulate the volatilization of COCs in the shallow aquifer. ISCO would also introduce oxygen to the aquifer which would enhance naturally occurring degradation processes.

6.2.5 Comparison of Selected Alternative to Performance Standards

This section provides an evaluation of the selected corrective measure with respect to RCRA performance standards as described in **Section 5.0**. The selected corrective measure consists of three parts (see **Figure 16** for remedy illustration):

- Focused in situ remediation using an ozone sparge curtain located between the upland groundwater impacts and the river in order to eliminate the exposure pathway. This technology will be proven in the field through the implementation of a pilot test. If this technology is shown to be ineffective, then another oxidant will be identified or aerobic biodegradation will be considered;
- Source zone excavation of VOC-impacted soils to the groundwater table and subsequent mixing of oxidant into the shallow aquifer materials prior to backfilling; and
- MNA to document aquifer restoration over time.

This remedy is consistent with the following site-specific attributes discussed in Section 5.2.2.

- The remedy addresses residual source material associated with both SWMU11 and building 16 releases, the former through excavation and ISCO (activated sodium persulfate), and the latter through ISCO (ozone).
- The remedy addresses the only completed exposure pathway for groundwater: discharge of impacted groundwater to river sediments by maintaining a treatment barrier between the upland aquifer and the river. Human health exposures are nullified through the use of a soil cap and an ELUR associated with the soil remedy and the GB groundwater designation.
- MNA is supported throughout the upland plume based on attenuation characterization data (bacterial counts and geochemistry). Ozone itself is a destructive technology, but also decomposes to oxygen, thus the ozone will provide an oxygen source to support aerobic biodegradation downstream of the reactive barrier.
- The remedy takes into account the fact that there are significant impediments to aquifer access most notably the FPA ELUR required to maintain the cap associated with the soil remedy~~former building foundations, footings, pilings and basement voids filled with crushed concrete~~.

This alternative is thus promulgated by this revised conceptual site model where:

- The remedy relies on existing natural degradation processes to address residual dissolved-phase mass in upland aquifer materials;
- It replaces the former IRM hydraulic containment system with an ozone sparge curtain reactive barrier placed between the upland and the river to meet the objective to treat the shallow and deep portions of the aquifer and protect the river receptor; and
-

- It treats residual source materials through excavation and oxidation. Treatment of the source will facilitate MNA in the main portions of the plume.
- It employs an ELUR that is necessary to implement the soil remedy to eliminate direct contact considerations and provide for long-term operation, maintenance and monitoring access.

6.2.6 Evaluation Criteria

6.2.6.1 Overall Protection of Human Health and the Environment

This remedy provides protection of human health and the environment:

- The ozone barrier breaks the GW/SW interaction pathway, thus protecting surface water and sediment quality in the river from impacts by Site COCs.
- Ozonation results in complete destruction of COCs (no treatment residual, byproducts, or contaminant – any excess ozone required to drive the degradation reactions to completion degrades into oxygen).
- In concert with the soil remedy (i.e. ELUR and soil cap), direct contact with residual dissolved mass is eliminated.
- The ELUR and remedy infrastructure: ozone generator, injection and monitoring wells, injection equipment, and soil cap, effectively and permanently address human and environmental risks in the short-term and long-term.
- The former P&T has shown that natural attenuation is effective to address residual dissolved mass in the long-term.
- In contrast to other oxidants that leave excess oxidant such as manganese or sulfate (from permanganate or persulfate respectively) in the treated groundwater, ozone sparging would only add dissolved oxygen. Ozone is short-lived in the environment. If any residual ozone remained in the groundwater that discharges to the river, it would be degraded to oxygen immediately upon contact with organics in the river water or sediment.
- Reducing or eliminating residual source materials in the upland portion of the FPA will facilitate MNA in the mid-plume areas.

6.2.6.2 Attain Media Cleanup Standards

This remedy will attain media cleanup standards:

- Ozone provides complete destruction of COCs (no byproducts, treatment residuals); as a result, MPS and GB standards for groundwater would be attained downgradient of the ozone sparging barrier.
- The former pump and treatment system has shown that hydraulic control is effective to meet the MPS and in so doing protect the river receptor.
- Natural attenuation upgradient of the ozone sparge barrier will address residual dissolved mass as it diffuses out of low conductivity saturated soils, rendering the mass flux negligible over time.
- Monitoring upgradient and downgradient of the barrier will be used to track and demonstrate attainment of MPS and GB standards.
- Residual source removal will facilitate attainment of the media cleanup standards by eliminating an ongoing source of impacts to groundwater.

6.2.6.3 Control the Sources of Releases

- The source of releases would be controlled by the soil remedy (soil excavation, local ISCO, ELUR and capping), coupled with the ozone sparge barrier to break the GW/SW interaction pathway, thus controlling the residual impacts to the river.
- Ozonation will result in complete destruction of COCs (no byproducts or treatment residuals).
- Long-term monitoring will ensure controls remain effective in the long-term.

6.2.6.4 Long-Term Reliability and Effectiveness

- Ozone has been shown to be an effective oxidant for the target COCs (Huling and Pivitz, 2006).
- Ozone sparge curtain has a long track record of commercial scale application (Kerfoot Technologies, 2015)
- Ozone can permeate the aquifer materials in two ways: transport as a gas phase and subsequent dissolution and transport into the water phase.
- Monitoring up-gradient and downgradient of the barrier will be used to track and demonstrate attainment of MPS for groundwater in the long-term.
- A pilot test will be used to confirm site-specific effectiveness and establish design parameters - with specific reference to radius of influence - for full-scale application.
- The permanent infrastructure (wells, piping, etc.) will support long-term effectiveness, and it can be adapted to an alternative amendment application, as the data support.
- Treating the residual source zone will enhance the long-term reliability and effectiveness.
- MNA will eventually replace the reactive barrier as aquifer restoration reduces the contaminant mass flux.

6.2.6.5 Reduction of Toxicity, Mobility, or Volume of Wastes

- By completely destroying COCs without generating any treatment residuals or byproducts, ozone sparging would completely eliminate the toxicity and mobility of the COCs of interest.
- Ongoing natural attenuation of residual mass located up-gradient of the barrier will result in the reduction, over time, in the total mass remaining and its mobility (reduced mass flux over time).
- The application will not mobilize contaminants as this is a weathered release present in adsorbed and dissolved phases only.
- In contrast to other oxidants that leave excess oxidant such as manganese or sulfate (from permanganate or persulfate respectively) in the treated groundwater, ozone sparging would only add dissolved oxygen. Ozone is short-lived in the environment. If any residual ozone remained in the groundwater that discharges to the river, it would be degraded to oxygen immediately upon contact with organics in the river water or sediment.

6.2.6.6 Short-Term Effectiveness

- This alternative would be effective in the short term because ozone, upon contact with the COCs, provides instantaneous destruction of Site COCs.
- Ozone is a powerful oxidant and appropriate health and safety precautions will be implemented to ensure it is handled and conveyed safely to the sparging wells. Because the

ozone would be generated on site as needed, no special health, safety, or handling will be needed off-site. Health and safety guidelines are noted in the References Section.

- In contrast to other oxidants that could put elevated levels of manganese or sulfate (from permanganate or persulfate respectively) and impact the river, the ozone treatment would if anything only add oxygen to the river. Ozone can't persist very long and even if it reached the river it would be degraded instantly upon contact with anything organic.
- See also criteria for long-term effectiveness as they also apply to effectiveness in the short-term.
- Source zone removal would have limited impacts on adjacent businesses and residences.

6.2.6.7 Implementability and Environmental Footprint

Site conditions support implementability in the following ways:

- There are no significant surface or subsurface impediments to treating Site COCs using an ozone sparge barrier in the vicinity of the bulkhead. The barrier would be oriented perpendicular to the groundwater flow direction and at the proper depths to intercept groundwater impacted with Site COCs at levels exceeding MPS and GB standards.
- The geology is unconsolidated sands and silts which is amenable to well installation at the required depths.
- The alternative does not require invasive work to be implemented in the upland residual impact area where there are significant subsurface impediments (foundations, footings and piers) that limit the accessibility of this area at the appropriate spatial scale.
- Long-term siting of remedy infrastructure and site access is guaranteed through the imposition of an ELUR, which in part is required for the soil remedy.
- An UIC permit will be required.
- The environmental impact of an ozone treatment system from a sustainability perspective is best characterized by pointing out that competitive oxidants like permanganate and persulfate and for that matter any of the biological treatment modalities require synthesis and shipment of chemicals, sometime across long distances (India, China, Eastern Europe). Ozone is generated on-site by passing air through a simple electrical arc.
- Source zone treatment is implementable with common heavy machinery (excavation, oxidant mixing).

6.2.6.8 Cost

The estimated costs for this corrective measure strategy are presented in **Appendix E**, as Alternative 4.

Estimating Assumptions

The following general assumptions were considered in developing the cost estimate for this alternative.

- The treatment barrier will be designed to remediate the shallow and deep zones that exceed the MPS. The estimated length of the treatment barrier is 200 feet (**Appendix D**). The treatment thickness is estimated at 40 feet, between 6 and 46 feet below ground surface (bgs) (**Appendix D**). The estimated number of ozone injection wells in the shallow zone is five

(5), and thirteen (13) in the deep zone. This is based on an estimated zone of influence of 15 feet. The estimated capital cost to install 18 ozone injection wells, six (6) monitoring wells in the shallow zone and six (6) monitoring wells in the deep zone, trenching and piping, procure and mobilize an ozone generator, electrical connection is $482,000. The estimated annual O&M cost is $154,000. This includes weekly O&M, electrical usage, system's evaluation, quarterly performance groundwater monitoring, and quarterly performance report.

- Continuous ozone sparging will occur for 5 years, while monitoring will continue for 30 y.
- The total 30 year cost is $2.3 MM.
- Costs are based on vendor experience with ozone remediation projects
- Actual costs will be based on competitive bids from drilling, trenching and piping vendors, electrical contractor, and ozone equipment.
- The number of injection and monitoring wells and well spacing as described above. The actual configuration will be based on a field pilot test.
- Performance monitoring includes laboratory analysis for VOCs and hexavalent chromium, and field analysis for pH, oxidation-reduction potential, and dissolved oxygen.
- Contractor markup, engineering design, and construction management percentage are based on conventionally accepted values.
- Any permits beyond those normally needed for the type of project and project conditions are excluded

6.2.6.9 Federal, State and Community Acceptance

- The remedy is not technically complex: Groundwater flows through a residual groundwater impact zone on its way to the river and in so doing transports dissolved-phase COCs. A curtain of ozone is injected into the subsurface between the upland and the river to destroy resident COCs before they are transported offsite. The sparge curtain is maintained through a surface infrastructure (trailer). Groundwater samples are collected upgradient and downgradient of the curtain to monitor effectiveness of the curtain and depletion of remaining residual mass located upgradient of the curtain.
- The remedy is an in-situ technology that has a small surface footprint, which will not create a significant visual effect.
- The remedy addresses risk-based standards through the combinatory use of the barrier (groundwater treatment) and an ELUR (maintain soil cap, allow access).
- Incorporating residual source treatment in the upland portion of the FPA will enhance the effectiveness of the ozone barrier and mid-plume MNA.

6.2.7 Evaluation Comparison to Other Groundwater Alternatives

This Alternative is an ISCO remedy, and for the reasons introduced above, ISCO has advantages over aerobic bioremediation technologies. As detailed above, using the oxidant ozone is considered the most appropriate ISCO application for the site conditions and remedial action objectives. While the ISCO remedy is more expensive than the biologically-based remedies, they are technically more robust given the site conditions, and this should reduce some uncertainty in cost, therefore rendering the ISCO remedy on par with the bioremediation with regard to cost. Further, treatment of the residual source material will enhance the effectiveness of the ozone barrier and the MNA of the mid-plume areas.

Detailed implementation, design, and performance monitoring plans will be developed in subsequent documents following implementation of the pilot test.

6.3 OWLA

To address RIDEM Regulations, BASF will remove or cover the soil with exceedances of the I/C DEC and impose an ELUR for this area to be approved by the RIDEM. The ELUR will include the following restrictions: non-residential use only, must employ a soil management plan for any invasive work conducted on the property, and must, on an annual basis, report to the RIDEM that the terms of the ELUR are being met.

~~In northern portions of the Site, an ELUR restricting future use, a soil management plan, limited surface soil removal and maintaining these areas by covering with clean soil and/or pavement/asphalt will be utilized to meet remedial objectives.~~

6.4 Pawtuxet River Sediment

Several technologies presented in the Stabilization Report (Woodward-Clyde, 1996) have already been constructed in the Production Area. The technologies that were identified to be protective of sediment and river quality include sediment excavation, disposal, capping, and extraction wells (hydraulic control system) for hydraulic control of on-site groundwater from migrating into the river. The groundwater extraction and treatment system operated from 1996 to 2010 when long-term monitoring data showed aquifer restoration was complete except for a recalcitrant area. The recalcitrant area was the subject of extensive remedial investigation (AECOM, 2012), and it is a subject of this CMS (Section 6.2).

Given the historic remedial measures completed for sediment at the Site, a long-term periodic monitoring program will be implemented to ensure the existing sand cap remains intact and protective. Monitoring frequency is initially proposed to occur at the first five year review (2021) and after major flood events between now and that time (defined by NOAA as a Pawtuxet River stage that exceeds 13 ft MSL at the USGS gage station 01116500). Under the monitoring plan, the sand cap will be sampled for PCB content to ensure that any remaining PCBs sequestered below the cap are not permeating the cap. Cores of the cap will be collected along the center line at upstream, midstream and downstream locations (3 cores) and samples will be collected for PCB analysis from the 0" to 3" and 3" to 6" horizons (2 samples per core). If PCBs exceed 1 ppm in any sample, additional investigation will be conducted to determine the source of the detections and appropriate remedial measures necessary to ensure protectiveness, if any. A detailed monitoring and sampling plan will be developed following this outline. At the time of the 5 year review, based on the data in hand, a decision will be made as to the permanence of the remedy and future monitoring requirements.~~Given the historic remedial measures completed for sediment at the Site, a long-term periodic monitoring program will be implemented to ensure the existing sand cap remains intact. Monitoring frequency is proposed to occur every five years and after major flood events (as defined by NOAA, Pawtuxet River at Cranston (CRAR1) stage exceeds 13 ft MSL). The sand cap will be sampled for PCB content under the monitoring plan to ensure that any remaining PCBs sequestered below the cap are not permeating the cap. If PCBs exceed 10 ppm in the sand cap, additional investigation will be warranted followed by a potential scenario where the sand cap is removed and/or re-established. A monitoring and sampling plan will be developed and provided under separate cover.~~

6.5 FWWTA

The selected remedy for the FWWTA includes No Further Action. The FWWTA is zoned for commercial use and currently is used as a landscaping operation. A risk assessment completed in 1995 (Ciba) determined that there were no significant risks associated with a conservative reuse scenario of an on-site resident (despite commercial zoning). The 200 ft Riverbank Wetland prevents development and soil management without RIDEM approval.

7.0 References

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Woodward-Clyde, Sediment IRM for the Pawtuxet River, 1996.

Tables

Figures

Appendix A

Soil Remedial Options – Conceptual Design Figures

- Figure A-1A – Low Occupancy Re-Use Scenario (PCB Removal >50 ppm) –
- Figure A-2 – High Occupancy Re-Use Scenario (PCB Removal >10 ppm)
- Figure A-3 – Strictest Remedial Standard (PCB Removal >1 ppm)
- Figure A-4 – Northern Parcel Areas Remedial Options

Appendix B

Soil Remedial Options - Conceptual Design Volume Calculations

Appendix C

Soil Remedial Options - Cost Estimates/Assumptions

Appendix D

Groundwater Remedial Options - Conceptual Design Figures

Appendix E

Groundwater Remedial Options Cost Estimates/Assumptions

Appendix F

Former Production Area Groundwater Bench-Scale Study Analytical Report and Pre-Design Investigation Data Summary Tables

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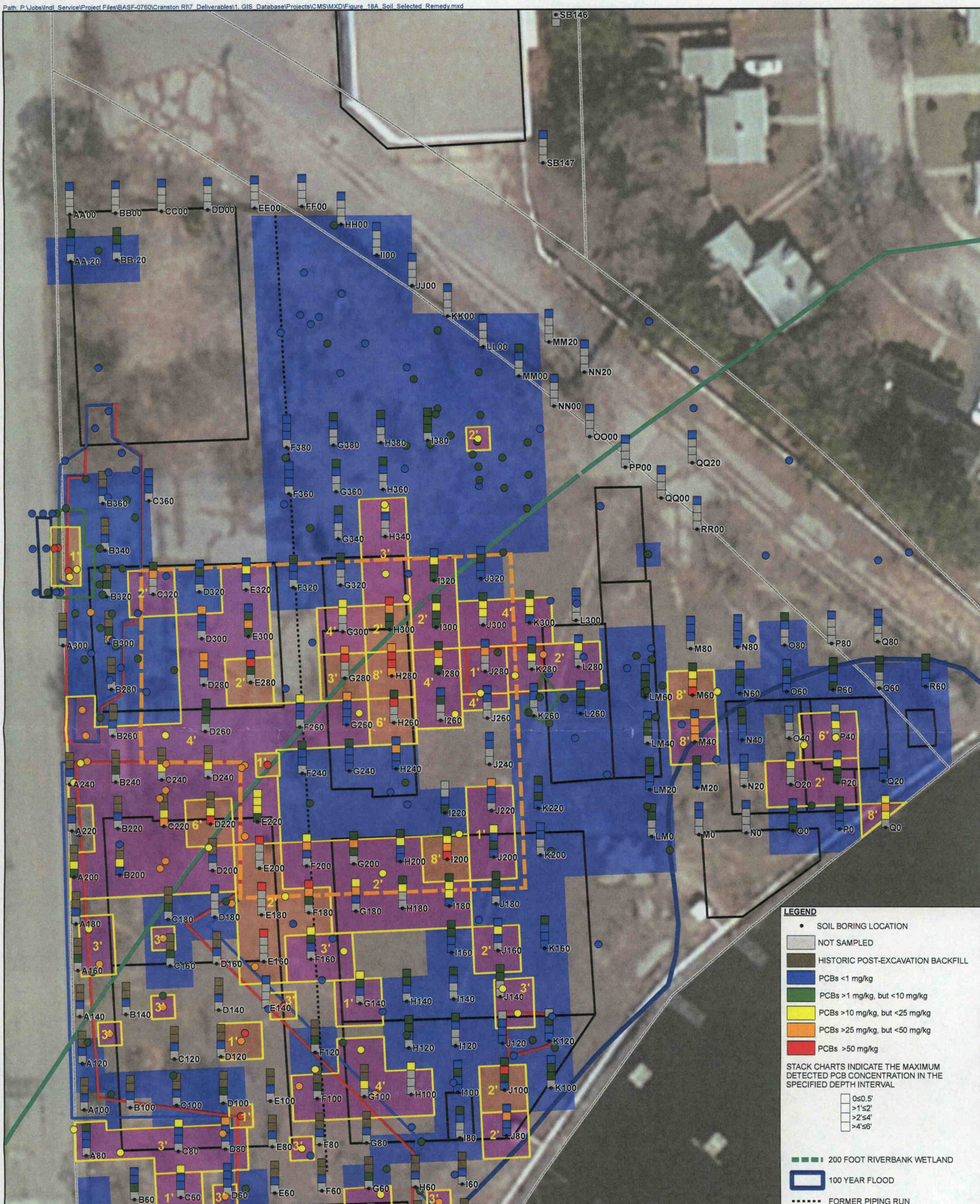

AECOM

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FORMER CIBA-GEIGY
CRANSTON, RI

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PRODUCTION AREA
SOIL SELECTED REMEDY
CORRECTIVE MEASURES STUDY

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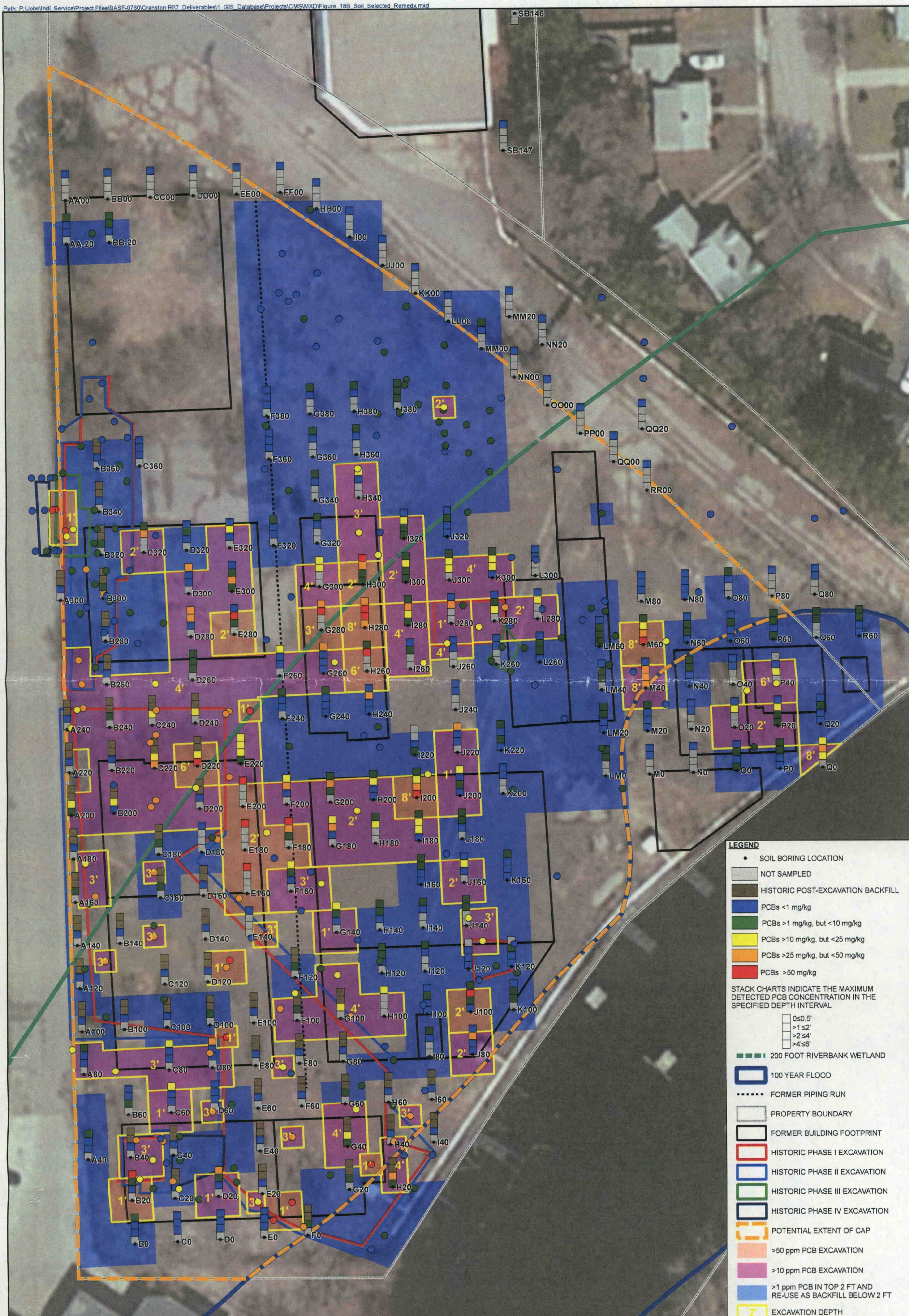

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PRODUCTION AREA
SOIL SELECTED REMEDY
CORRECTIVE MEASURES STUDY

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